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"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Meetings of the AMS—1961

New York City	National Meeting and Annual Business Meeting	23–26 January
Chicago, Ill.	General Meeting	21–23 March
Washington, D. C.	General Meeting with AGU	18–21 April
Davis, Calif.	General Meeting with Pacific Division of AAAS	20–22 June
Miami, Fla.	Conference on Hurricanes	27–30 June
Honolulu, Hawaii	Tenth Pacific Science Congress	21 August–6 September
Kansas City, Mo.	Ninth Weather Radar Conference	23–26 October
Tallahassee, Fla.	General Meeting	14–16 November
St. Louis, Mo.	Fourth Conference on Agricultural Meteorology with ASA	28–29 November
Denver, Colo.	With the Annual Meeting AAAS	26–31 December

(Additional meetings and conferences to be scheduled)

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1960

A Year of Excitement and Progress

THOMAS MALONE, *President*
American Meteorological Society

EVEN the most blasé observer could not fail to detect the sense of excitement and progress that pervaded the field of meteorology during 1960. The mood of the present era was perceptively stated by Past-President Petterssen in these same columns last year when he wrote: "The time has come for us to lift the science of meteorology out of a state of neglect and place it on a level of prominence among the other physical sciences."

The transition is now well under way. From the traditional point of view that meteorology is solely occupied with weather prediction, we have passed to an awareness that its chief concern is with the *science* and the *technology* of a gigantic and complicated physical system, coupled at its lower boundary to an earth-ocean complex and intertwined at its outermost reaches with the other physical systems comprising our universe. As a science and a technology, the concerns of meteorology are two-fold: To extend knowledge through basic research and to apply this knowledge so that man may live and carry on his activities in closer harmony with his atmospheric environment.

There has been a healthy reawakening on the part of the national community to the fact that these two pursuits are inseparable. A strong and vigorous scientific effort cannot long be maintained without a flourishing and vigorous technology—nor can the technology of weather analysis and forecasting accomplish what is required without the basic research effort from which to derive its vitality.

One of the year's outstanding accomplishments specifically illustrates the dual character of our total meteorological effort. Surely, the year 1960 will go down in meteorological history as the occasion on which man was first successful in establishing observational platforms outside the main mass of the atmosphere, from which he could view in its global entirety the salient physical characteristics of the atmosphere, such as the radiation balance and synoptic cloud systems. It is clearly too soon to assess the impact of this achievement with respect to the extension of knowledge or to the utilization of the information thus made available in weather forecasting. Nor will such an appraisal be possible until the primordial steps taken during the past year are replaced by the more advanced observational systems already under development to describe the thermal structure of the lower stratosphere and upper troposphere and hemispheric scale. No great act of faith is required, however, to believe that the rewards will be well worth the effort. It is worth remarking, however, that whereas the period of gestation for EXPLORER VII and TIROS I

was of the order of a decade, the exponential curve of scientific progress is bound to carry us forward at a rate so great that it will tax our technical, scientific, and management skills to plan, to organize, to interpret, and to use.

The past year was also notable for the outline of a better understanding of the composition, physical and electrical characteristics, the photochemistry, and the motions in the upper layers of the atmosphere that began to emerge from the observations of solar and terrestrial phenomena during the International Geophysical Year. The increments of knowledge combined to provide an impressive justification for this brilliantly conceived and superbly conducted international scientific program.

TIROS I was launched by a Thor Able rocket at 0640 EST, 1 April 1960, at the Atlantic Missile Range, Cape Canaveral, Florida. Photo courtesy of U. S. Weather Bureau.

Even as promising progress was made in exploring the outer reaches of the atmosphere, plans were being laid for a comprehensive attack on the equally important problem of the interaction between the atmosphere and the ocean. In anticipation of the Indian Ocean Expedition, which will reach its peak of activity several years hence, a program has been drawn up to exploit the unique scientific opportunity afforded by this imaginative expedition to study these interactions in an area of the world where the monsoon circulations provide an ideal setting for studying at several scales the atmospheric circulation and the exchange of heat, water vapor, and momentum between the ocean and the atmosphere. If these plans are brought to fruition, the pattern of international collaboration among the scientists of many nations, so fruitfully achieved during the International Geophysical Year, will be even more solidly advanced.

Pursuing further the progress made during the past year in developing the science of meteorology, we may note the significance that should properly be attached to the establishment of a National Center for Atmospheric Research in Colorado by the National Science Foundation and the University Corporation for Atmospheric Research. Intended as a focal point for an interdisciplinary assault on some of the basic scientific problems of the atmosphere, and operated in intimate association with the basic research efforts and the academic programs of our universities, this Center under the guidance of Dr. Walter Orr Roberts promises to fulfill a need that has been recognized by several groups within and outside the meteorological community.

A complementary effort of major importance to both science and technology was initiated in Oklahoma by the establishment of the National Severe Local Storms Research Project, a cooperative program of the Weather Bureau, the Federal Aviation Agency, the National Aeronautics and Space Administration, the Air Force, and the Navy. Intended to provide the needed detail for a three-dimensional description of the mesoscale structures that spawn local storms, this project also complements the research studies of the National Hurricane Research Project in contributing to a better understanding and ability to antici-

pate those extreme circulations in the atmosphere which annually take such a heavy toll of life and property. This program, too, is a forthright recognition of the inseparable link that binds together basic research and the application of the results of that research in weather prediction.

Space does not permit enumeration of but a small number of major research undertakings initiated or advanced in 1960. The collaborative effort involved in the Meteorological Rocket Network promises to provide information vital to an elucidation of the interconnection between the upper and the lower portions of the atmosphere. This serves as only one example of many other programs that might properly be mentioned.

In parallel with the augmented effort in basic research, there were several developments intended to advance the technological aspects of our profession. The impact of automation became more apparent with the installation at the National Meteorological Center of a curve plotter which will draw a map in approximately 30 seconds. Experimentation continued with mathematical models utilizing the primitive equations. Steps were taken at NMC to close the gap between numerical prediction of the three-dimensional field of motion and forecasts of cloudiness and precipitation.

A large-scale program to integrate recent developments in automated observations, high-speed communication, data processing, and forecasting techniques into a weather observing and forecasting system was carried on under a joint program sponsored by the Air Force, the U. S. Weather Bureau, and the Federal Aviation Agency. The NANWEP program of the U. S. Navy at Monterey pushed forward vigorously with a program to exploit the advances in automation to service the meteorological needs of the Navy.

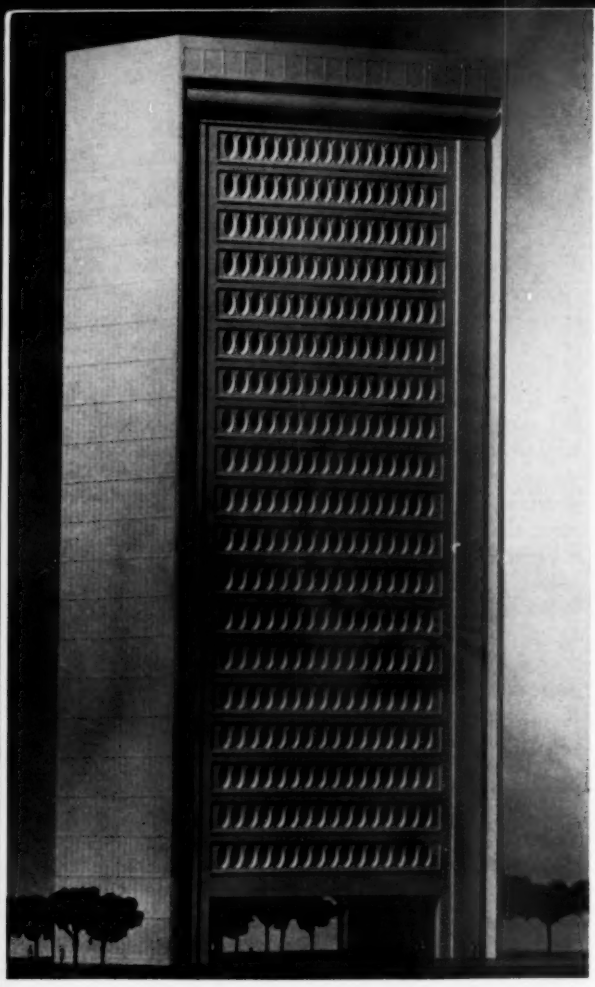
Substantially increased attention was given to the ideas advanced by Brier and Thompson more than a decade ago to the problem of incorporating forecast uncertainty into the decision-making process where weather is an important factor in operations in order to optimize those decisions and to enhance the economic value of weather information.

Finally, in the applied area tribute should be paid to the dedicated forecasters and observers all over North America who spared no effort to provide the best possible service to the millions depending on weather information each day.

The conclusion, however, should not be drawn that our progress is dependent on the number and magnitude of efforts requiring great sums of money and large numbers of people. Just as important is the contribution of the individual research worker carrying on his studies in the relative quiet of a university campus. In point of fact, it is no understatement to say that the university occupies the key role in the research and development programs that are now underway. More often than not, it is the creative thinking of a Verner Suomi or a Lewis Kaplan that provides the basic concept around which the larger programs are developed.

The universities, moreover, are the primary source from which emerge the scientists and professionals to carry on the programs. The ferment and vitality in the universities is evident from such activity as the movement on several campuses to establish cross-disciplinary centers which in themselves create the proper context and environment for teaching and research in meteorology. The groundbreaking for a new building at M.I.T. to house such a group, the initiation of a meteorological program at Columbia, the establishment of an Atmospheric Research Laboratory at the La Jolla campus of the University of California, and the program in atmospheric sciences at Harvard are only a few of the examples that might be cited. Others are the new programs at Colorado State University and the University of Oklahoma. While bricks and mortar are not the primary measure of scientific activity, the splendid new facilities for atmospheric physics at the University of Arizona, the fine physical environment of UCLA, and the projected plans at Florida State University are indicative of the recognition on the part of the university administration to our departments of meteorology. And the increase in the number and attractiveness of fellowship opportunities bodes well for attracting into our field the quantity and quality of students urgently needed.

The rapid growth and the maturing of the total meteorological effort on this continent poses certain challenges and presents many



A new Center for the Earth Sciences will rise in 1961–62 on the Massachusetts Institute of Technology campus at Cambridge, Massachusetts. The above model of the 20-story reinforced concrete building shows the new structural expression selected. The Department of Meteorology will occupy the top five floors. Weather instruments and weather radars will cap the roof of the building.

opportunities for our Society. The Fortieth Anniversary Year of the American Meteorological Society was also a year of progress for the Society—progress toward the accomplishment of plans laid in the past, and progress in plans for the future.

The plans for an appropriate home for our headquarters were realized on January 29th when the secretariat moved into the magnificent old Bulfinch House at 45 Beacon Street in Boston. The vision and the plans for a stronger, more active Society laid by Professors Rossby, Houghton, and their associates in the middle forties were justified and realized by the activities of the Society during the past year. It seems worthwhile to take note of some of these activities, not with the thought of generating complacency over accomplishments, but to establish a sort of benchmark against which further progress of the Society may be measured.

Total membership now stands at almost seven thousand compared with less than three thousand at the end of 1945. The number of meetings held and the number of pages published can be either dreary statistics or an exciting measure of the scientific and professional activities of the Society. It hardly seems necessary to go back to comparative figures for 1945 to be convinced that the latter is the case for our meetings and publications. In 1960 there were eleven national meetings and conferences in this country and one international conference in Italy with the Unione Nazionale Antigrandine. Incidentally, the strength of the ties that bind meteorology to the other disciplines was evident in the fact that seven out of the eleven national meetings and conferences were held in collaboration with other groups.

In view of the fact that publication is one of the vital aspects of our Society's activities, one cannot fail to be impressed by the fact that our *Journal of Meteorology* published 692 pages of technical and scientific papers, and the *Bulletin* brought to our members 724 pages of articles, news, programs, and records of Council deliberations. Over 280 pages of *Meteorological Monograph* were published, and 274 pages of *Weatherwise* added to the bill of fare available to our reading membership. The importance of the more than 2000 pages of our *Meteorological and Geoastrophysical Abstracts* was attested by its designation as one of the world's principal abstracting journals in geophysics by the International Union of Geodesy and Geophysics at its Twelfth General Assembly in Helsinki last summer. Just as an exercise of more interest than value, if one of our members really wished to read *all* of our regular publications, he would have to read an average of more than 75 pages each week just to keep completely current with the Society's publications.

Meaningless as is this exercise with figures, it does suggest a basic problem in information retrieval about which the Council has already begun to think.

But sheer number of pages are not a valid measure of the value of the publication program of a society. Even as we take justifiable pride in the quality and the diversity of our publications, so must we constantly be alert to how they might be improved. Among plans for the continued vigor of the Society's publications program, the Council approved broadening the coverage of our abstracting periodical to include all of geophysics except hard-rock geology. Similarly, it is hoped that the distribution of *Weatherwise* can be expanded so that it will be an effective window to bring to the general public the interesting developments in our field. Discussions are under way for preparing a "Compendium of the Atmospheric and Planetary Sciences" to replace the *Compendium of Meteorology* published a decade ago. In recognition of the distinct yet related scientific and technological aspects of activities in meteorology, plans are being prepared for publication of a *Journal of the Atmospheric Sciences* and a *Journal of Applied Meteorology* to succeed the *Journal of Meteorology*. These changes all require considerable time and thought to insure a sound and dynamic publications program attuned to the needs of our times.

With the continued growth of meteorology, the demands on our Society are steadily increasing and the Council has studied in considerable detail the internal organization of committees and boards through which is carried on most of the scientific and professional activity. The objective of this analysis is to provide an efficient framework within which the committees and boards may function and to free the Council from detail so that it may perform its responsibility of determining broad policy for the Society in the light of major developments in meteorology.

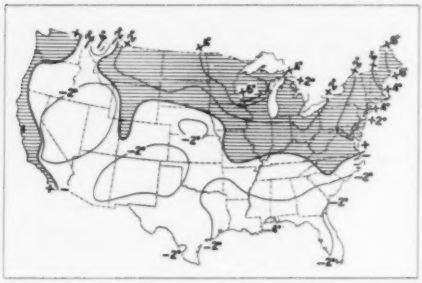
As one of its contributions to the stimulation of interest in careers in meteorology and to the enrichment of the intellectual activity in the meteorological community, the Society with support from the National Science Foundation has moved ahead with the imaginative plans developed by Past-President Petterssen and described by him in *Weatherwise* a year ago. Several distinguished foreign scientists, including Prof. L. Ramdas and Prof. E. Palmen, visited the United States as part of the visiting scientist program. Lectures and informal talks were given at more than a hundred colleges and universities as part of our visiting lecturer program. The pre-college science center had another eminently successful year. Plans are well along for the preparation of a series of monographs on various atmospheric subjects, badly needed career guidance material is under preparation, and pilot work on meteorological motion pictures is under way.

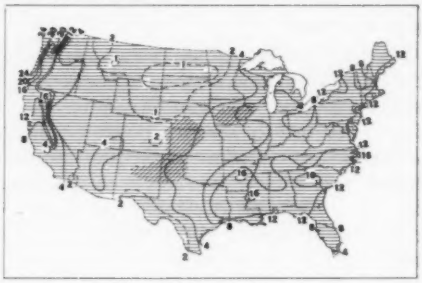
The quickened tempo of activity associated with the profound changes taking place in our field presents us with an array of opportunities that are equaled only by the number and magnitude of the problems to be solved if these opportunities are to be seized and turned into contributions to the knowledge we wish to acquire and the services we wish to provide. In view of the magnitude and complexity of the total task and the limited human and material resources, it seems to me that five requirements must be kept clearly in mind as we proceed with this task:

1. We must marshall these resources and organize our efforts in the most harmonious, efficient, and effective manner that is possible.
2. We must spare no effort to augment our scientific and technical manpower.
3. We must do all in our power to provide sustained and stable support for basic research.
4. We must demonstrate consumate skill and wisdom in achieving a proper balance in expanding our basic research and improving the excellence of our technology.
5. We must plan soundly and imaginatively and labor unselfishly to be sure that our American Meteorological Society fulfills its obligations of services to the public at large, to the weather-minded layman, to the professional meteorologist, and to the general community of scientists.

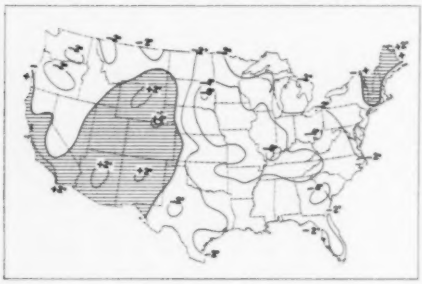
THE WEATHER BY SEASONS 1960

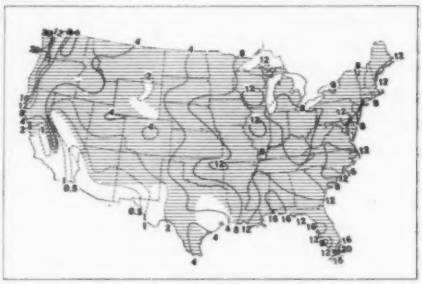
WINTER (DECEMBER–FEBRUARY) 1959–1960



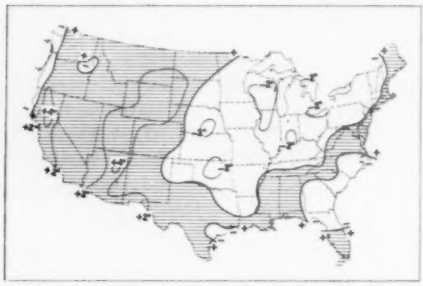


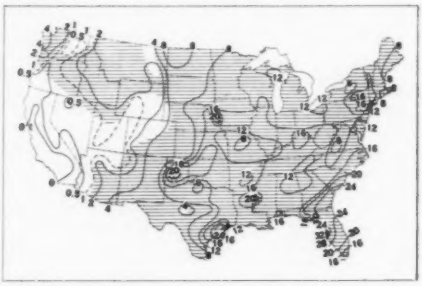
SPRING (MARCH–MAY) 1960



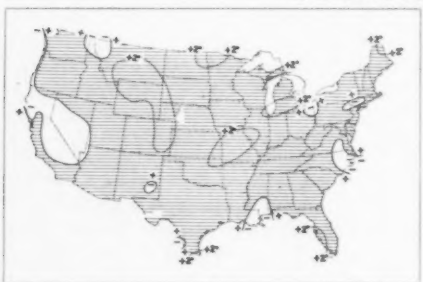


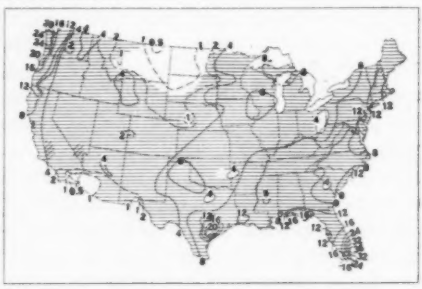
SUMMER (JUNE–AUGUST) 1960





FALL (SEPTEMBER–NOVEMBER) 1960





Charts show the departure of the temperature from normal in degrees Fahrenheit by seasons 1960. USWB charts.

Charts show the total precipitation in inches by seasons 1960. USWB charts.

The Circulation and Weather of 1960*

WILLIAM H. KLEIN, *Extended Forecast Section, U. S. Weather Bureau, Washington, D. C.*

WINTER

THE mean 700-mb contours for the winter season of 1959–60, given by the solid lines in figure 1, show that the circulation over North America was dominated by a sharp ridge in western Canada and a broad trough extending from Newfoundland southwestward into Mexico. Widespread storminess and precipitation prevailed in this trough, and total amounts were more than twice the winter normal in a band from the Great Lakes to the Southwest. A generally wet winter in the United States can also be attributed to strong anticyclonic activity over Canada with consequent southward displacement of the storm tracks. The nature of this blocking is brought into sharp focus by the departure from normal of mean 700-mb height, given by the dashed lines in figure 1. A huge area of positive height anomaly reached from 40°N to the North Pole, with a center 480 feet above normal near Baffin Island. To the south heights averaged lower than normal from

* This paper is based on a series of articles on the weather and circulation of each month appearing routinely in the *Monthly Weather Review*.

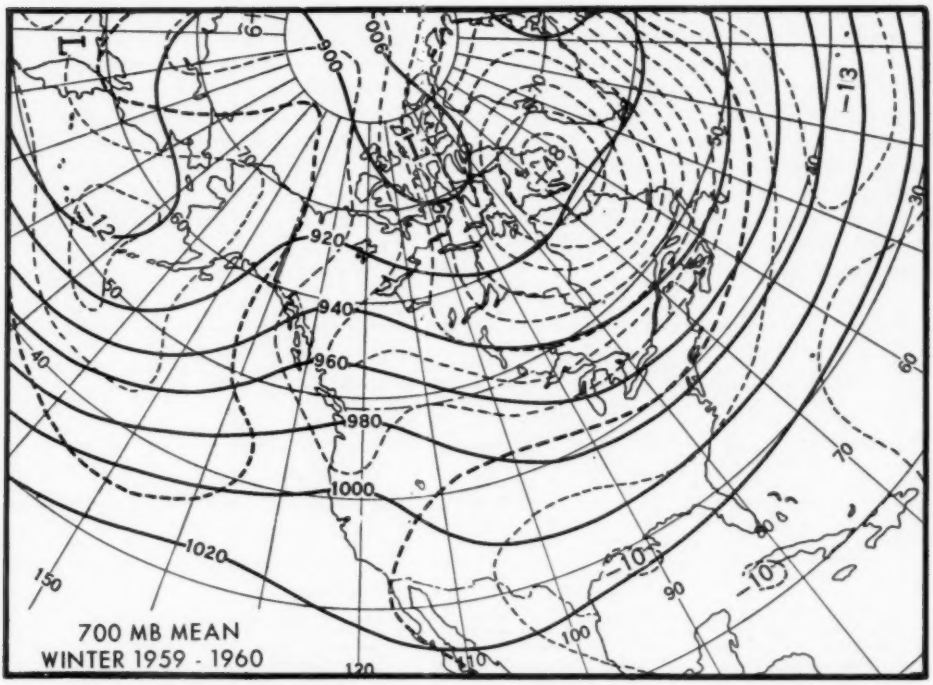


FIG. 1. Mean 700-mb map for the winter season (Dec. 1959, Jan. 1960, and Feb. 1960). Solid lines are contours and dashed lines are height departures from normal. Outstanding feature is large center of positive anomaly in northeast Canada, with negative departures to the south, a pattern typical of blocking. (Reproduced from the *Monthly Weather Review*.)

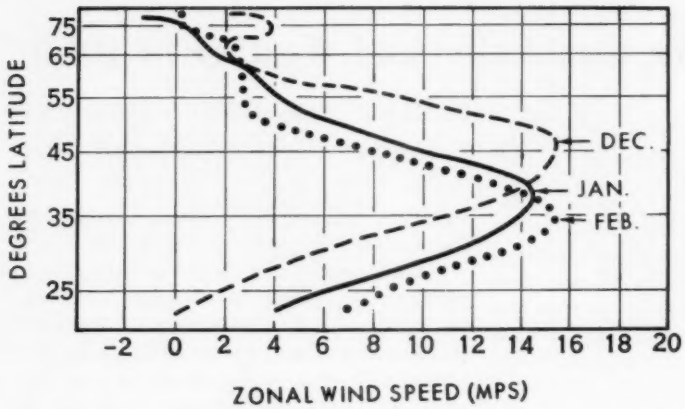


FIG. 2. Mean zonal wind speed profiles at 700-mb in the Western Hemisphere for three winter months. Note progressive southward shift of the westerlies from December (dashed) to January (solid) to February (dotted).

40°N to Central America, so that the jet stream and associated cyclone tracks were depressed south of normal.

An interesting feature of this winter's blocking pattern was the manner in which it evolved. Figure 2 shows the profile of mean zonal wind speed averaged over the Western Hemisphere at the 700-mb level during each of the three winter months. In December 1959, the belt of west winds was displaced north of normal, reaching maximum speed at latitude 46°N. However, during the next two months the peak westerlies moved steadily southward to a minimum latitude of 34°N in February. Consequently, the westerlies progressively weakened from 40°N to 60°N but strengthened from 40°N to 20°N.

This evolution is portrayed in somewhat different fashion in figure 3, which gives the time variation of 5-day mean values of the zonal index in the Western Hemisphere, a measure of the speed of the 700-mb westerlies between latitudes 35°N and 55°N. The general trend of this index was downward throughout the winter season, from a high of 14 meters per second in mid-December to a low of 5 mps at the end of February.

The downward trend of the zonal index was accompanied by a similar trend of surface temperature in much of the United States. In December 1959, temperatures averaged above normal in most of the nation as fast westerlies spread mild Pacific air masses across the entire continent. As the westerlies

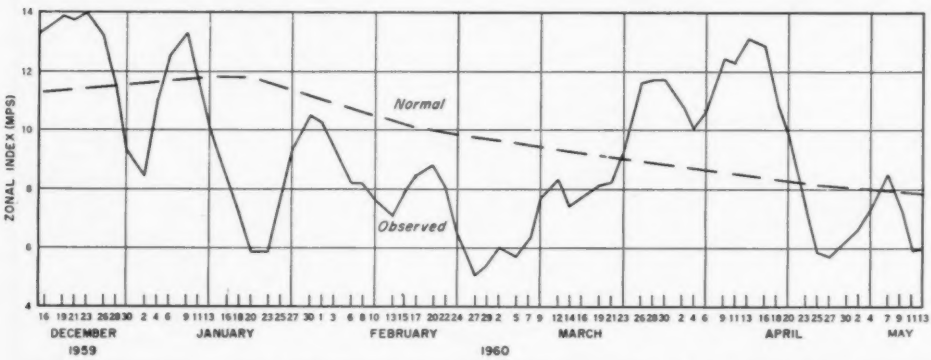


FIG. 3. Time variation of 700-mb zonal index in meters per second for the Western Hemisphere in the latitude belt 35°–55°N from December 1959 until May 1960. Solid lines connect 5-day mean values (plotted on last day of period), while variation of normal index is shown by dashed line. The index was above normal in December and April but generally below normal in the other four months.

moved southward and weakened in January 1960, the weather turned considerably colder, and the belt of above normal temperatures was confined largely to the northern half of the country. In February there was a further increase in the intensity and extent of the cold air, and temperatures averaged below normal in nearly all areas except the Northeast. When the zonal index reached its minimum at month's end, surface temperatures were also the lowest of the season, with weekly averages as much as 30°F below normal in the Central Plains.

SPRING

The mean 700-mb circulation over North America during March was similar to that of the winter season (fig. 1) and consisted of a strong ridge along the West Coast and a deep trough in the East. Blocking continued to dominate the pattern as 700-mb heights averaged above normal in eastern Canada but below normal in the eastern United States. This block was so tenacious and widespread that the 5-day mean zonal index was continuously below normal from 11 January to 23 March (fig. 3).

The blocking and low-index combined with stronger than normal northerly flow to produce an extremely cold month throughout the eastern two-thirds of the United States. A great many stations over an extensive area reported their coldest March of record, and some old records were broken by a wide margin. An important factor contributing to the abnormal cold was the establishment of an extensive and deep snow cover over areas where snow is not normally found at this time of year. Figure 4 shows that total snowfall during March was greater than normal (shaded) in nearly all of the eastern half of the United States, except the Gulf States. More than six times the normal amount fell in a broad band extending from the Middle Atlantic States to the Central Plains. Much of this snow was produced by cyclones moving along a track depressed southward by blocking. The effect of the snow cover was

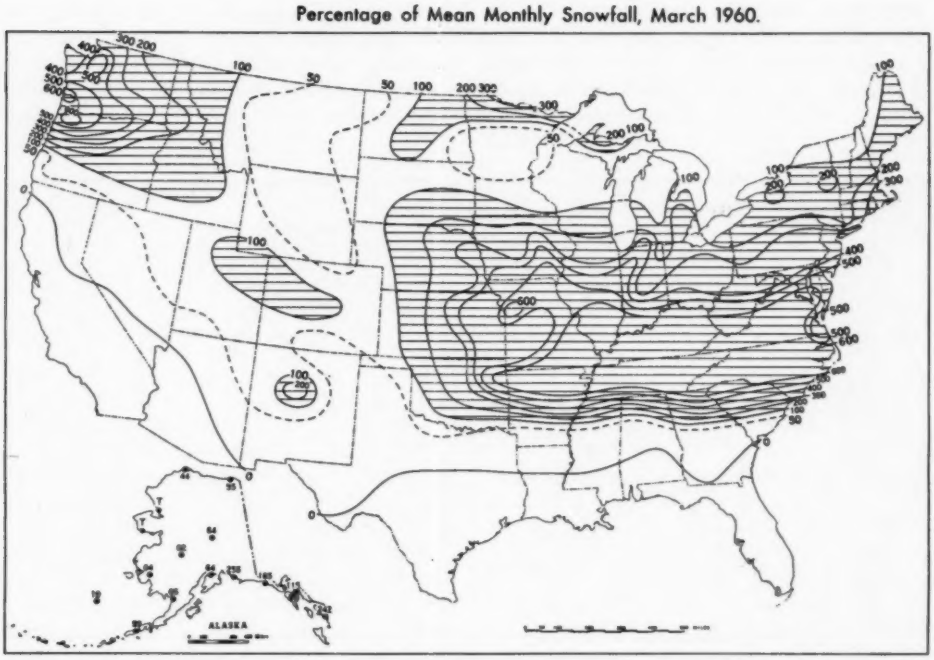


FIG. 4. Percentage of mean monthly snowfall observed during March 1960, with greater than normal values hatched. Over six times the normal amount fell from the Middle Atlantic States westward to Missouri. (Reproduced from *Climatological Data, National Summary.*)

to prevent appreciable warming of polar outbreaks as they progressed southeastward from the Canadian source region.

The zonal index rose steadily during the latter half of March and then remained above normal for one month from 23 March to 22 April (fig. 3), as blocking relaxed and strong west winds carried mild Pacific air across most of the United States. During the second half of April a strong ridge aloft became established over the East Coast for the first time since December 1959. Vigorous warming resulted in many new records for maximum temperature at eastern cities. The heat wave was more spectacular because of the record-breaking cold which had preceded it during March, so that winter seemed to give way abruptly to summer during a brief interval. At the same time a deep trough over the Far West produced sharp cooling with frost west of the Continental Divide, heavy snow in Montana, and tornadoes and floods in central sections.

During May the circulation reverted to the pattern of March and the winter season (fig. 1), as strong blocking resumed over eastern Canada and a deeper than normal trough occupied the eastern half of the United States. The zonal index again dropped below normal (fig. 3), and the axis of maximum westerlies was displaced southward over most of the Western Hemisphere. As a result May was a rather cool and stormy month over much of the country.

A striking feature of the May circulation was unusual retrogression of strong vortices around the North Pole. This is illustrated in figure 5, showing the tracks and intensities of two 5-day mean pressure centers at sea level, one an anticyclone and the other a cyclone, which dominated the polar circulation for over a month. Examination of daily weather maps reveals that the retrogression of both cells was practically continuous from 30 April until 4 June.

SUMMER

During June and July the mean circulation and weather patterns were quite similar. Although blocking relaxed and the zonal index rose, 700-mb heights still averaged slightly above normal in eastern Canada but below normal in the eastern United States. As a result both months were rather cool and wet over the eastern half of the United States. One reason is indicated in figure 6, giving the primary tracks of daily cyclones and anticyclones during July. A branch of the paths of both dipped abnormally far south into the country, augmenting the southward penetra-

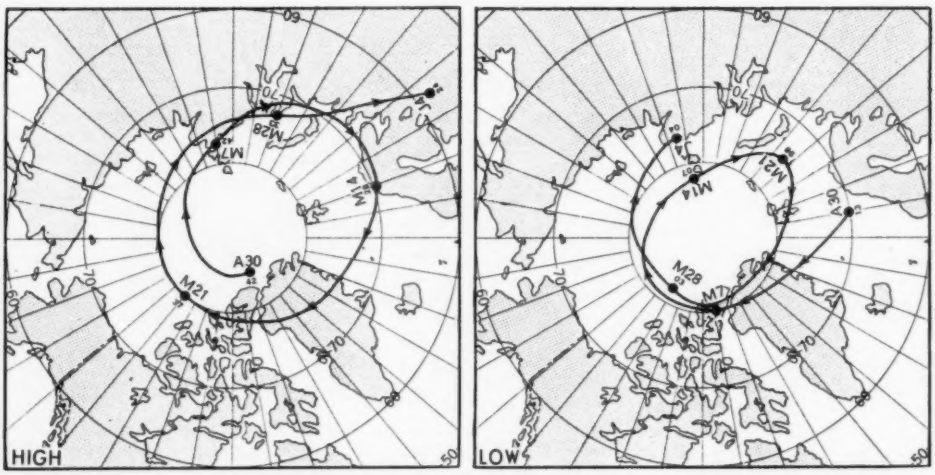
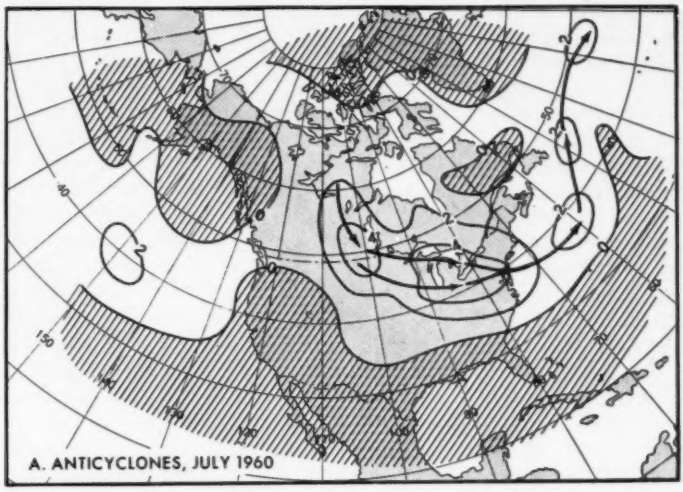


FIG. 5. Tracks of 5-day mean polar vortices during May 1960 at sea level for anticyclone (left) and cyclone (right). Positions shown are one week apart from 30 April until 4 June, with month and middle day of period above, and intensity of center in millibars below. Continuous retrogression around the pole lasted for five weeks. (From the *Monthly Weather Review*.)



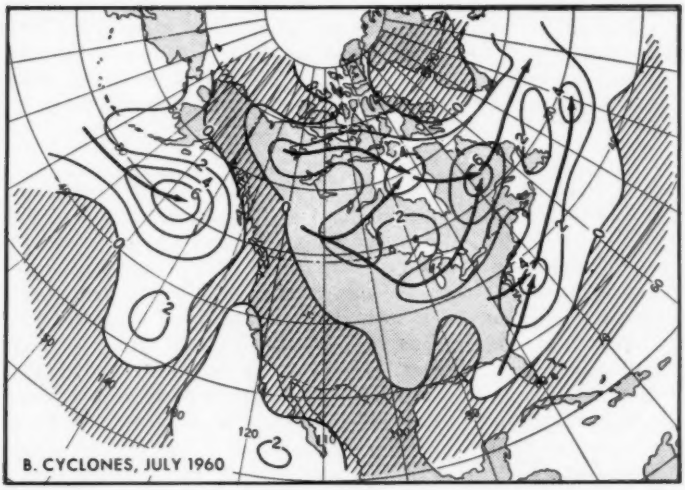


FIG. 6. Number of passages of (A) Highs and (B) Lows within equal-area boxes (66,000 square nautical miles) on daily sea level maps during July 1960. Primary tracks are indicated by heavy arrows. Note the zero frequency (hatched) of migrating systems west of the Continental Divide. (From the *Monthly Weather Review*.)

tion of cool Canadian air and spreading heavy showers from the Great Plains eastward.

In the western half of the United States, on the other hand, hot dry weather prevailed under a strong ridge aloft. Northward displacement of the jet stream led to a complete absence of migratory systems, either high or low, as shown by the zero frequencies (hatched) in figure 6. As a result of the virtual absence of strong outbreaks of cool Pacific air masses, dry air of continental characteristics dominated the West, and the influx of solar radiation was largely unimpeded. Sustained high temperatures, low humidity, and little rainfall brought extremely critical forest fire conditions throughout the Western States. These conditions were most marked in the Southwest during June and in the Northwest during July.

In August the temperature pattern over the United States underwent almost a complete reversal from the regime which had persisted during the previous two months. This was the third consecutive year in which July–August persistence of monthly mean temperature has been subnormal. The reversal was brought

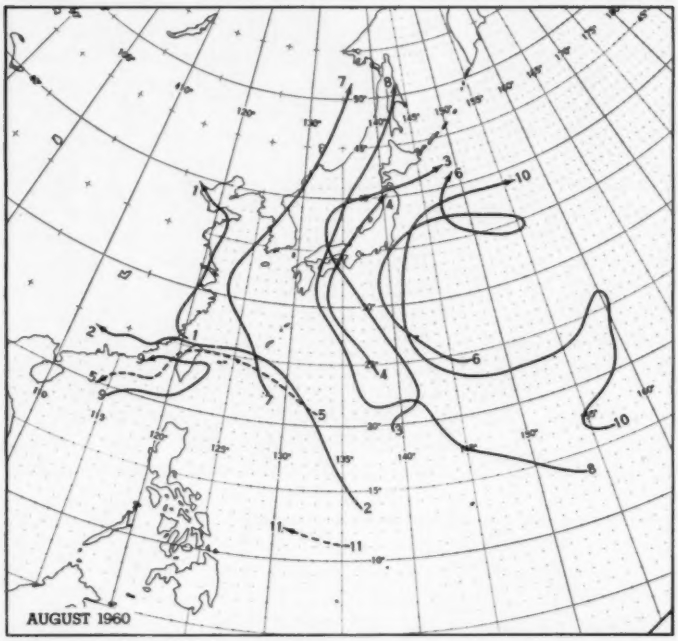


FIG. 7. Smoothed tracks of tropical storms in the western Pacific during August 1960. Solid lines represent those storms which were classified as typhoons at some point in their life history; dashed lines are storms which never reached typhoon intensity. Tracks are numbered chronologically from 1 to 11, the greatest number of storms on record for August (reproduced from the *Monthly Weather Review*)

about by marked deepening of a mean trough in western North America, with concomitant strengthening of the Bermuda High in the Southeast. Cool moist air entering the trough from the Pacific alleviated the drought and set new low temperature records in the Pacific Northwest, but the hottest weather of the summer prevailed in the East under the ridge aloft.

A highlight of the hemispheric circulation during August was the unprecedented number of tropical storms in the western Pacific. A total of 11 were reported during the month, of which nine reached typhoon intensity, compared to a normal frequency in August of only about four. The tracks of these storms, reproduced in figure 7, show that three crossed Japan and three affected Formosa. This unusual tropical activity was related to stronger than normal southeasterly flow on the monthly mean 700-mb chart between a deep low center over Formosa and a strong high southeast of Japan.

FALL

The general circulation during the fall season was markedly zonal in character and remarkably uniform from month to month. Through most of September, October, and November the prevailing westerlies of middle latitudes were strong, and the zonal index averaged above normal. The resulting mean pattern is illustrated in figure 8 for the field of sea level pressure. As is typical of high index, the oceanic lows were deep and zonally elongated, the subtropical highs were well developed, and the polar highs were rather weak.

The arrowed curves in figure 8 are schematic representations of the principal tracks of migrating cyclones and anticyclones at sea level during the fall of 1960. They were determined by inspection of the track charts published monthly by the U. S. Weather Bureau in *Climatological Data, National Summary*. In accordance with the high-index nature of the circulation, the storm tracks were well-defined across Canada and the oceans, but there was little cyclonic activity in the United States. Likewise, cold anticyclones entering the United States from Canada and the Arctic were mainly of the "glancing" variety, i.e., they curved sharply eastward along the northern border of the nation; while the mean high centered over Virginia was made

up mainly by anticyclones of Pacific origin moving along the southern track in figure 8. Cold arctic and polar air masses were prevented from penetrating southward into the country by fast westerly flow along the northern border. Consequently temperatures averaged above normal in practically all portions of the nation during the fall season.

The strong westerlies combined with a mean trough along the West Coast to produce greater than normal precipitation in nearly all areas west of the Continental Divide. Copious Pacific moisture was released by orographic lifting and by upward vertical motion induced by frontal passages. In descending the slopes of the Rocky Mountains, however, the air was subject to foehn drying, so that fall precipitation totalled less than one-quarter of the seasonal normal in parts of the Northern Plains. In the Southern Plains, on the other hand, rainfall was quite heavy, and over twice the normal amount fell in parts of Texas. The origin of this moisture is well indicated by the mean sea level isobars in figure 8 which show strong southeasterly flow from the Gulf of Mexico curving cyclonically into the Southwest.

One of the highlights of the fall season was the weather in western Europe. Unusually heavy precipitation was accompanied by flooding in many areas, and only the northern portions of Scandinavia and the British Isles received substantially less than normal amounts. This weather was associated with southward displacement of the storm track in the Atlantic, a deep mean trough aloft along the coast of Europe, and an intense cyclonic center of action west of Scotland (fig. 8). Abnormally strong Atlantic westerlies, depressed by blocking over Greenland, dropped much of their moisture upon entering Europe. Much of the rain fell during passage of vigorous storms which sped across the Atlantic, reached their maximum intensity near the coast, and then moved inland and weakened. The effect of these storms is well indicated by the cyclonically curved isobars over Europe on the mean sea level map (fig. 8).

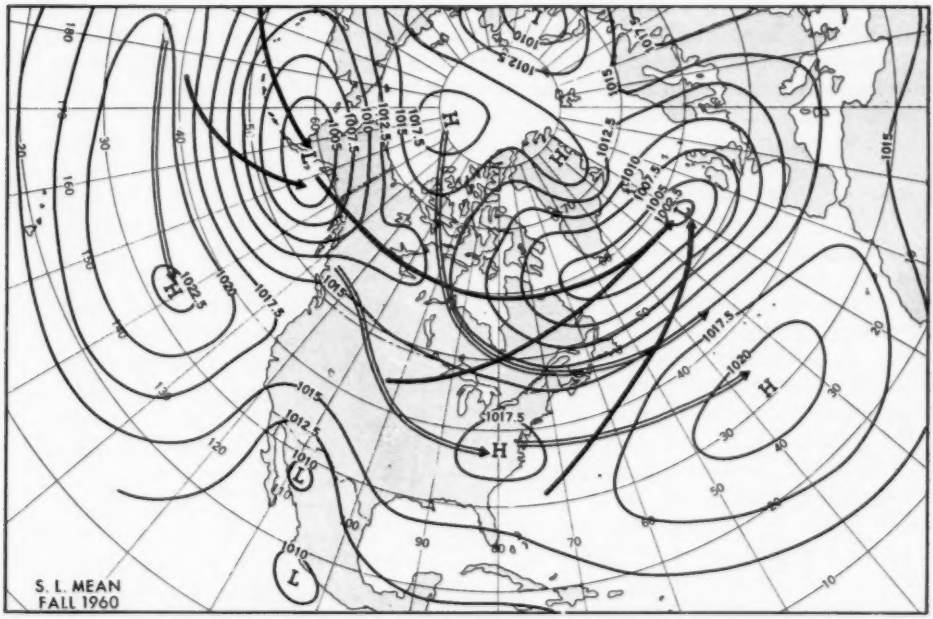


FIG. 8. Mean sea level map for the 1960 fall season (September, October, and November). Thin solid lines are isobars giving pressure in millibars. The prevailing tracks of daily pressure centers are indicated by heavy solid arrows (for lows) and open arrows (for highs). Fast westerly flow resulted in mild weather over the United States and heavy rains in Europe.

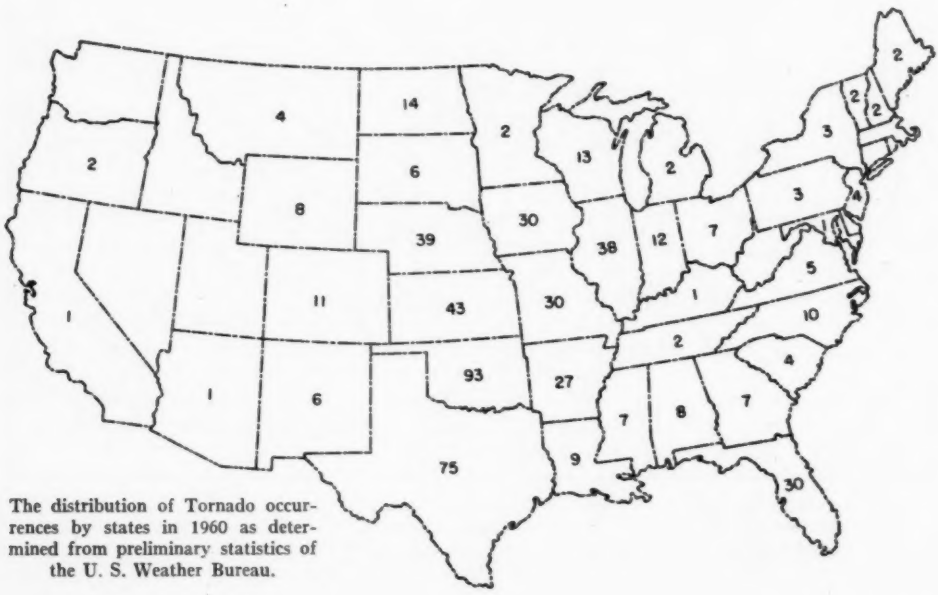
Tornadoes During 1960

ROBERT G. BEEBE, *Midwest Weather Service, Kansas City, Missouri*

DURING 1960 a total of at least 564 tornadoes occurred. This figure represents the sum of those reported in the Weather Bureau's monthly *Storm Data* from January through October plus unofficial compilations by the author for November and December. The frequency of tornadoes in 1960 is about the same as for the past several years since tornado reporting and forecasting were put on a national scale. In addition to the tornado reports, there were also hundreds of funnel clouds and waterspouts observed. The distribution of 1960 tornadoes by states, as shown on the accompanying map, demonstrates that most of the occurrences were in "Tornado Alley," although Florida again had as many as Iowa.

The number of 1960 deaths directly attributed to tornadoes totaled only 51. This is the lowest number since 1954 and less than one-fourth the average of 213 over the past 45 years. Injuries ran near 735 compared with approximately 700 in 1959. It is interesting to note that there were over 150 fatalities due to lightning and thunderstorms during 1960, some three times the number attributed to tornadoes.

The first important family-type tornado outbreak of 1960 struck in Kansas and Oklahoma on 28 April. While there were only three fatalities, injuries numbered 64. Most of these occurred in the Oklahoma City area where severe thunderstorms, numerous small funnels, two-inch hail, heavy rain, and one large tornado were reported. Property damage in the Oklahoma City area alone was estimated at over $4 million. Wichita in Kansas also was visited by tornadoes, funnels, three-inch hail, and damaging winds, but, fortunately, there were only six injuries and no deaths. Thirteen tornadoes were reported in Kansas and Oklahoma on this date.



The distribution of Tornado occurrences by states in 1960 as determined from preliminary statistics of the U. S. Weather Bureau.

Radar photo from WSR-3 at Topeka, Kansas, 19 May 1960, at 1834.5 CST. The range markers are set at 5-mile intervals. Of particular interest is the knob on the end of the hook, located nine miles to the northwest. This knob coincided in time and space with the tornado. Photo courtesy of the U. S. Weather Bureau.

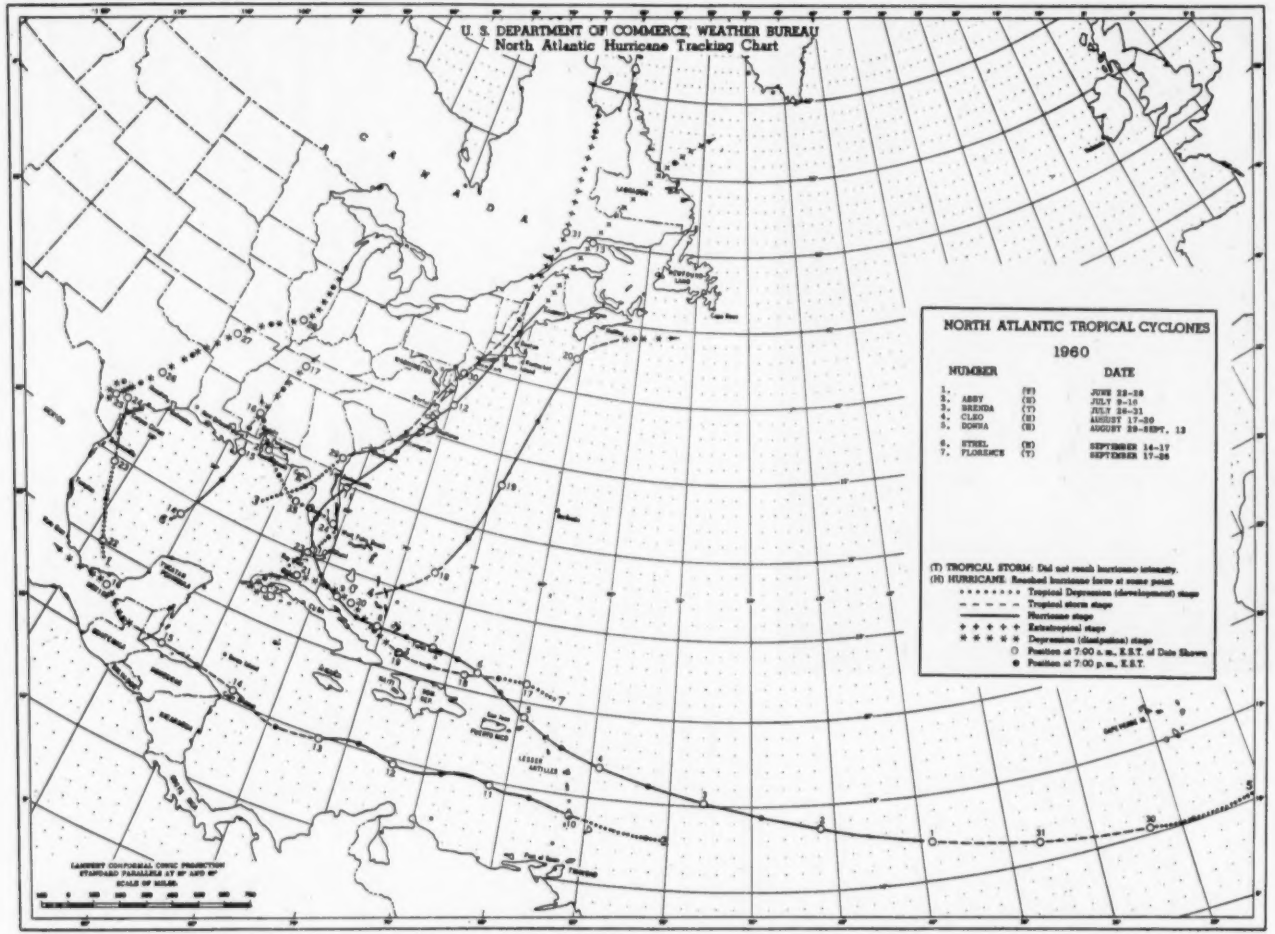
On 4 and 5 May the most devastating series of storms of the year swept through Oklahoma and Kansas. On these two days, some 35 tornadoes were observed and, of course, numerous funnel clouds. These storms were the most destructive of the year with 33 lives lost (over half of the total for 1960) and 260 injuries. Most of these destructive storms struck in the northeast corner of Oklahoma near Tulsa. The tornado near Tulsa was described as "a huge, white, barrel-shaped cloud that stayed completely on the ground." Damage from these storms amounted to several million dollars.

Oklahoma and Kansas were again visited by a series of tornadoes and severe storms on 18 May. Although six tornadoes were observed, there was only one fatality and four injuries. Most of the damage during this series of storms resulted from large hail and strong thunderstorm winds.

One of the most interesting tornado outbreaks of the season, from a research point of view, occurred in northeast Kansas on 19 May, although numerous tornadoes and other severe storms struck in Oklahoma and Missouri this same day. There was a total of 26 tornadoes, one death, and nearly a hundred injuries. In northeast Kansas, at least six tornadoes were confirmed along a 75-mile path from 40 miles west of Topeka to Ft. Leavenworth. The first of this series of tornadoes dipped to the ground at 1714 CST and the last dissipated over Ft. Leavenworth at 2033, with damage estimated near $7 million. There were several factors about this tornado of unusual interest to researchers. For one thing, the storm setting passed within eight miles of the Weather Bureau Airport station at Topeka where both upper-air and radar observations are taken. The WSR-3 radar was in operation during the time of the tornadoes and some outstanding radar photos were obtained. An extensive ground damage survey was made along with a complete aerial photographic record of the damage paths by the Kansas Air National Guard. Thus, considerabe interesting material for research were secured.

An unusual aspect of this series of tornadoes in northeast Kansas caused many observers, especially during the earlier stages, to have difficulty in recognizing these as tornadoes. Some photos during the earlier stages also confirmed that they were not the kind usually shown in photos. Some witnesses described the tornado as a black, whirling mass

(Continued on page 29)


U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
North Atlantic Hurricane Tracking Chart
NORTH ATLANTIC TROPICAL CYCLONES
1960
NUMBER
DATE
1. (T) JUNE 28–29
2. ABBY (H) JULY 9–12
3. BRENDA (T) JULY 28–31
4. CLEO (H) AUGUST 17–20
5. DONNA (H) AUGUST 29–SEPT. 13
6. ETHEL (H) SEPTEMBER 14–17
7. FLORENCE (T) SEPTEMBER 17–26
(T) TROPICAL STORM: Did not reach hurricane intensity.
(H) HURRICANE: Reached hurricane force at some point.
Tropical Depression (development) stage
Tropical storm stage
Hurricane stage
Extratropical stage
Depression (dissipation) stage
Position at 7:00 a.m., E.S.T. of Date Shown
Position at 7:00 p.m., E.S.T.
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS 17° 30' AND 45°
SCALE OF MILES

The Hurricane Season of 1960

PAUL L. MOORE, *Weather Bureau Office, Miami, Fla.*

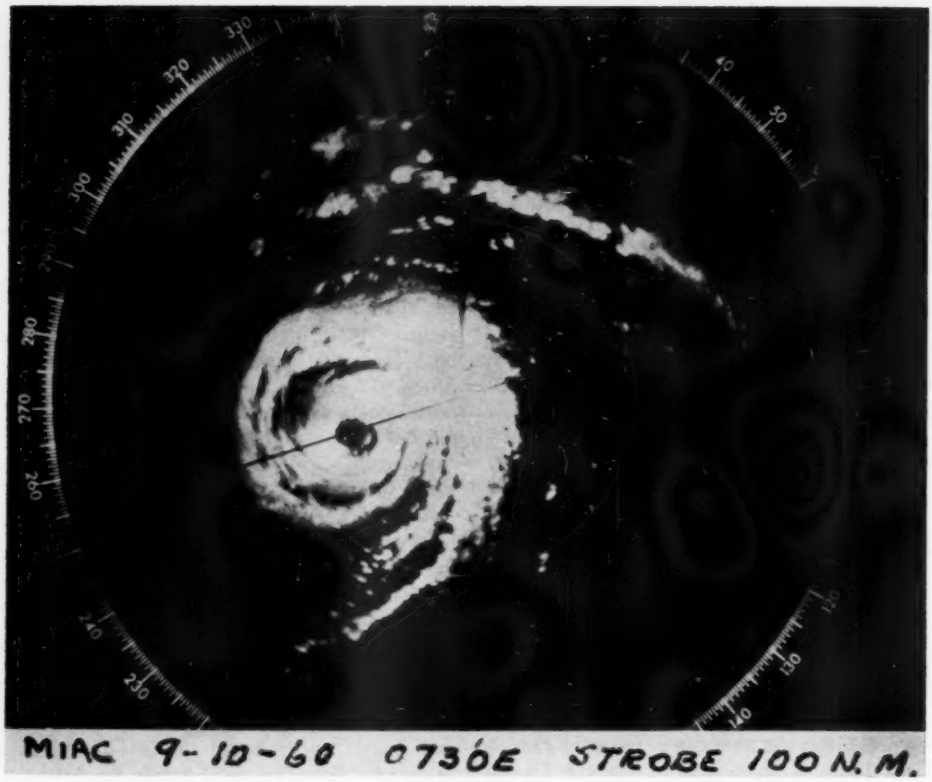
A TOTAL of seven tropical cyclones developed in the Atlantic-Caribbean-Gulf of Mexico area in 1960, qualifying the hurricane season as somewhat below normal in activity compared to the average frequency of ten per year over the past two or three decades. Only two storms, Donna and Ethel, brought hurricane-force winds to the coast of the United States. In all, four storms grew to hurricane intensity, compared to an average of five in recent years. The relatively low activity, however, is not reflected in the property damage figures of some $400 million for the United States. All but about $2 million of the total was contributed by Donna in her rampage up the Florida peninsula, along the Atlantic Seaboard, and into New England. The enormity of this destruction places her in a category with such notable hurricanes of the past as Carol and Hazel of 1954 and Diane of 1955. Considering the property losses as an index of potential casualties, the number of fatalities in the United States was remarkably low, totalling 57. Fifty were attributed to Donna; seven occurred in the unnamed first storm of the season.

Donna was the first major hurricane to strike Florida since 1950. However, residents of the Middle Atlantic States and New England, who might have looked for a return to more traditional hurricane paths to signal an end to the cycle of high storm frequency in their areas, could find little encouragement in Donna's behavior. Although other tropical cyclones have given hurricane winds to Florida and the Middle Atlantic States, or to the latter area and New England, she displayed an unprecedented lack of favoritism as the first in 75 years of record (2) to hit all three of these areas with full hurricane-force winds.

Frequently the first tropical storm of the season develops during June in the Gulf of Mexico. This was the case again in 1960. A disturbance was detected by reconnaissance in the extreme southwestern Gulf on 22 June and moved northwestward to the Texas coast near Corpus Christi on the night of 23–24 June. It was of storm intensity only briefly, just before reaching land, and was never named. July contributed two tropical cyclones to the 1960 list. In the middle of the month, Hurricane Abby crossed the Caribbean from the Windward Islands to Central America. Storm Brenda originated in the northeastern Gulf of Mexico on 28 July, but did not show the typical structure of a tropical storm until it had moved to the coast of the Carolinas the following day. Since the track was over land much of the time, Brenda never reached hurricane strength. Cleo formed northeast of the Bahamas in mid-August and moved northeastward as a small hurricane, finally dissipating off Nova Scotia without having seriously threatened land areas.

The major hurricane of the season, and the most long-lived, was Donna whose infamous career began off the west coast of Africa in late August and spanned the first two weeks of September. The track across the Atlantic and up the Atlantic Seaboard from Florida to New England was the longest of any of the 1960 storms. Such persistence is a frequent characteristic of August hurricanes, many of which originate in the Cape Verde Islands area.

On 14 September, as the extra-tropical remnants of Donna moved northeastward from Labrador, activity shifted to the central Gulf of Mexico with the development of Hurricane Ethel. A noteworthy feature of this storm was its detection by an automatic weather station in the central Gulf. Ethel was very intense for a brief period, with winds of 140 knots, but weakened rapidly to barely hurricane strength as it approached the Mississippi coast. The final storm of the season, Florence, was relatively unimportant except for some heavy rains it produced in south Florida. Florence originated north of Puerto Rico on 17 September and moved westward to the Florida Straits, then took an erratic course across the western tip of Cuba, northward through south Florida, then across the north-



The eye of Donna as photographed on the WSR-57 radar at the U. S. Weather Bureau, Miami, Florida. The center at 0730 EST, 10 September 1960, was located about 25 miles south of Everglades City. Markers are 50-mile intervals. Polaroid photo by L. F. Conover, National Hurricane Research Project.

eastern Gulf of Mexico to the vicinity of Pensacola. Of minimal storm intensity and during much of its history, it had winds of only 20 to 30 mph.

The tracks of the 1960 storms are shown in figure 1. A brief summary of the individual storms follows. Since an earlier issue of *Weatherwise* included articles (1, 3, 5) on the history of Donna in the United States, no attempt will be made to duplicate this information.

UNNAMED TROPICAL STORM OF 22–28 JUNE

This storm developed from an area of disturbed weather observed by reconnaissance flights in the southwestern Gulf of Mexico on 22 and 23 June. No winds of greater than about 35 knots were reported on either flight. However, when the storm moved inland south of Corpus Christi, Texas, on the night of 23–24 June, it had increased somewhat in intensity and sustained winds of 40 to 50 mph and gusts of 60 mph were reported near the center. Heavy rains of 5 to 15 inches accompanied the dying storm northward through Texas and resulted in considerable flooding. Reports indicate that seven persons were drowned in the high seas or the subsequent floods. Property damage, mostly from the floods, totalled about $3.6 million.

ABBY

Abby developed from an easterly wave which was growing into a tropical storm as it moved through the Windward Islands on 10 July. The increase to hurricane intensity occurred in the extreme eastern Caribbean and

the center then followed a westerly course near the 15th parallel for the next three days. The maximum winds of 90 to 100 mph decreased to about 60 mph as the storm passed south of Jamaica on the 13th, but Abby had re-intensified to hurricane strength when she skirted the northern coast of Honduras early on the morning of the 15th. Six lives were lost on St. Lucia and widespread damage to property and crops occurred there and at Martinique. Crop losses were heavy near the storm path through Central America, but no deaths were reported.

BRENDA

A weak circulation in the northeast Gulf of Mexico began intensifying on 28 July. It soon accelerated northeastward, moving into Florida near Cross City and subsequently skirting the Atlantic Coast to New England. Brenda was not named until she began to show more definite signs of tropical storm structure on the 29th, but some squalls on the central portion of the west coast of Florida reached about 60 mph. Waves of ten feet or higher, superimposed on tides ranging from 3 to 5 feet, caused considerable beach erosion as well as the destruction of numerous small craft. Some flooding occurred in the Tampa area as a result of rains which totalled up to 13 inches. The highest sustained wind reported was 58 mph at Cape Hatteras. The principal effect along the Atlantic coast was heavy rain which was generally beneficial. No deaths were attributed to Brenda.

CLEO

Hurricane Cleo spent her entire life at sea, developing some 300 miles northeast of Nassau, Bahamas, on 18 August and moving northeastward to die over the cold waters southeast of Nova Scotia. Cleo attained hurricane strength late on the 18th and probably reached her maximum intensity with about 90 mph winds late on the 19th when she was approximately 300 miles southeast of the southern New England coast. There was no known loss of life or damage from this small hurricane.

DONNA

Donna was the major hurricane of the season and the most destructive ever to strike Florida. She originated near the Cape Verde Islands, off the west coast of Africa as did many of the previous notable hurricanes to

A street scene on Craig Key, Florida, on 10 September 1960 during passage of Donna. Photo by C. H. True, NHRP.

Wreckage of house on Lower Matecumbe Key, Florida, shows typical structural damage by wind and waves of Donna. Photo by C. H. True, NHRP.

hit the state. Actually, it appears that the increase to hurricane strength took place near longitude 40°W on 1 September, although the easterly wave in which the storm formed passed through the Cape Verdes on 29–30 August. Donna's movement during the first few days was towards the westnorthwest at about 17 knots, somewhat above the climatological mean speed. A well-established high pressure area to the north prevented recurvature and the hurricane rapidly increased in size and intensity. When the first reconnaissance flight penetrated the eye near latitude 14°N, longitude 49°W on the afternoon of 2 September, maximum winds were already hitting 120 knots. Only minor variations in strength were noted from then until the center reached the Leeward Islands on 5 September. The eye passed over Barbuda, St. Barthelemy, St. Maarten, and Anguila. Thirteen persons lost their lives and over 200 were injured, while property damage was extensive.

Donna caused minor damage in the Virgin Islands as she continued towards the westnorthwest, passing to the north of the islands and some 85 miles off San Juan, Puerto Rico, on the 5th of September. Although the highest winds at San Juan were only 27 knots, torrential rains southeast of the hurricane resulted in serious floods in the northern and eastern portions of the island. Despite the issuance of flood warnings by the Weather Bureau, 107 persons lost their lives in the rapidly-rising waters. A number of the tiny islands of the southeastern Bahamas fell directly in the path of Donna as she temporarily assumed a more westerly course after passing Puerto Rico. Turks Island was slightly to the south of the center and escaped the highest winds but received over 20 inches of rain, much of this in a 12-hour period. When the eye passed over Ragged Island, winds were estimated at 150 knots after the anemometer failed at 130 knots. Mayaguana was battered by hurricane-force winds for 13 hours, and many of the residents took refuge in buildings of the missile-tracking base. The center passed well to the south of Nassau. Therefore, the northwestern Bahamas missed the worst of the storm. Property damage, exclusive of that to military installations, which is not known, totalled $600,000. Although only the most substantial buildings were left standing on those islands exposed to the full force of the hurricane, there was no reported loss of life.

On 9 September, Donna skirted the northeast coast of Cuba, brought gales and heavy rain to much of the island, then headed toward the Florida Keys. The center crossed over the middle Keys between 0200 and 0300 EST, 10 September, accompanied by almost

indescribable destruction (fig. 2) from the 13-foot storm tide and winds estimated to have reached at least 155 knots in gusts. Additional deepening had occurred over the warm waters of the Florida Straits where the central pressure dropped to 930mb/27.46″, the lowest in Donna's history. It will be recalled that the lowest sea level pressure ever measured in the western hemisphere—892mb/26.35″—was observed in this same area in another famous storm, the Keys Hurricane of 1935. The extreme violence of these storms offers support for theories (4) relating maximum intensity of tropical cyclones to sea surface temperatures, since the waters surrounding the Keys are among the warmest in the hurricane belt.

Donna left a broad path of wreckage as she curved northward and northeastward across peninsular Florida, with great destruction from the Keys northward to the Naples-Fort Myers area and heavy damage through the central portion of the state and along the east coast. The reader is referred to the *Weatherwise* articles mentioned earlier (1, 3, 5) for details of Donna's history from Florida northward through North Carolina and up the Atlantic Coast into New England. By the evening of 12 September, the center was in Maine, still surrounded by squalls of hurricane force. Cold air entering the circulation at this time ended Donna's life as a tropical cyclone and she continued northeastward through eastern Canada as a frontal disturbance.

ETHEL

Hurricane Ethel was a violent but short-lived storm. It was detected on 14 September by the Navy's automatic weather station (MAMOS: Marine Automatic Meteorological Observing Station) in the central Gulf of Mexico, proving beyond doubt the utility and value of such stations. This was the first season in which MAMOS had been moored in the Gulf to supplement the observations available from surface ships and reconnaissance aircraft. Ethel intensified rapidly and reconnaissance aircraft measured a central pressure of 972mb/28.70″ and winds of 140 knots on the afternoon of the 14th. During the night of 14–15 September, probably as a result of cool, dry air entering the circulation, the intensity decreased markedly. When the center reached the coast near Biloxi, Miss., the lowest pressure was 981mb/28.97″ and the highest wind reported was 78 knots, with gusts to 90 knots, at Venice, La. The storm tide was generally 2 to 5 feet from the mouth of the Mississippi eastward to St. Marks, Fla., with one report of 7 feet just east of the Mississippi. The storm continued to weaken as it moved northward to Tennessee by the morning of the 17th. There was no loss of life in Ethel. Property damage was estimated at $1.1 million.

FLORENCE

The last tropical cyclone of the season, Florence, barely qualified as a tropical storm. It began as a broad, poorly-defined circulation some 200 miles to the north of Puerto Rico on 17 September, with maximum winds of 30 to 40 mph, then weakened and became even more diffuse as it continued westward off the north coast of Cuba the next few days. On 21–22 September, the remains of the storm drifted southward and became almost stationary near the western tip of Cuba. Slight regeneration occurred late on the 22nd and the weak depression then began a meandering course that took it into southern Florida near Lake Okeechobee, northwestward into the Gulf of Mexico, and finally, inland again near Pensacola. Gusts reached 52 mph in a squall at Vero Beach, Fla., when the low was nearest that station, but winds associated with the depression after 19 September were generally 30 mph or less. Rains of 3 to 6 inches, falling on ground already saturated from the rainfall of Donna, caused some local flooding in Florida. This was the only significant damage from Florence, and the rainfall over the eastern Gulf states proved beneficial to crops.

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Drifts up to 25 feet high line highway at Pompey southeast of Syracuse in New York's snow belt. Photo shows accumulation on 10 March 1960 when snow depths were near maximum for the season. Wide World Photos.

Some Noteworthy Snows of 1959-60

DAVID M. LUDLUM

NEW ENGLAND

THE only noteworthy storm in November occurred on the 28–30th as frozen precipitation fell across the northern portion of the New England area. In northwestern Vermont a heavy glaze downed power lines and trees while farther east snows up to 12″ fell from northeastern Vermont across to Maine. First Connecticut Lake (1660′) in New Hampshire had a November total of 31″ to make an excellent start for a heavy snow season there.

The first heavy snow in December did not come until the 21–22nd when a white mantle spread over southern sections with accumulations of about 6″ in southeastern Massachusetts and Rhode Island. A major storm hit the whole area on the 28–29th just in time to supply a good blanket for holiday skiers. Up to 18″ fell across northern New England, forcing cancellation of all air flights and greatly delaying holiday traffic. Along the coast gale force winds plus a full moon combined to raise tides to the highest point for 50 years, reminiscent of the great post-Christmas storm of 1909.

January produced four main snowstorms in the area. On the 13th from 5″ to 10″ fell across Massachusetts with the greatest depths in the Berkshires. On the 16th Maine had a very heavy fall with 8″ to 15″, and this was followed three days later by 8″ to 14″ more on the 18–19th. On the latter dates more snow also visited southern New England with 4″ to 8″ generally. A final January storm on the 28th produced rain, sleet, and snow in southern New England with some Massachu-

setts points receiving 5″ to 10″ and Maine points up to 10″. At Enosburg Falls, Vermont, in the lee of Lake Champlain, 45″ fell in January—the greatest depth on the ground was at Pinkham Notch in New Hampshire with a cover of 39″ on the 28th.

The major storm of February occurred on the 19–20th when a low center cut across southern New England. Hurricane force winds were experienced on the Maine coast and tides in Long Island Sound again approached record levels. Snow, sleet, and rain crossed the area with snow accumulations to the north of the storm's track being very heavy. Norfolk, Connecticut, had 14″ and up to 30″ fell in some parts of southern and central Maine where Hiram had 28.5″ of new snow to increase the amount on the ground to 54″. The greatest monthly total for February was measured at First Connecticut Lake: 49,9″.

By far the major event of the winter arrived in early March when a truly *great* snowstorm swept across southern New England to deposit the deepest single-storm totals in Weather Bureau history at some Massachusetts points. In Connecticut depths ranged from 8″ to 13″ in the south; inland the Danbury and Hartford area had 13″ to 15″; and the peak total for Connecticut was measured at Putnam with 23″. In Massachusetts, amounts ranged from 10″ in the western part of the state to 30″ in the extreme east. Blue Hill Observatory (640′) near Boston reported 30.3″ for the greatest single-storm total in the 76-year history of the station. At Boston 19.8″ fell for the greatest storm total since records commenced in 1871. A general average of 20″ to 30″ covered much of southeastern New England. Southern Vermont and southern New Hampshire also received falls close to 20″, but amounts tapered off quickly farther in the interior. See *Weatherwise,* April 1960, 59.

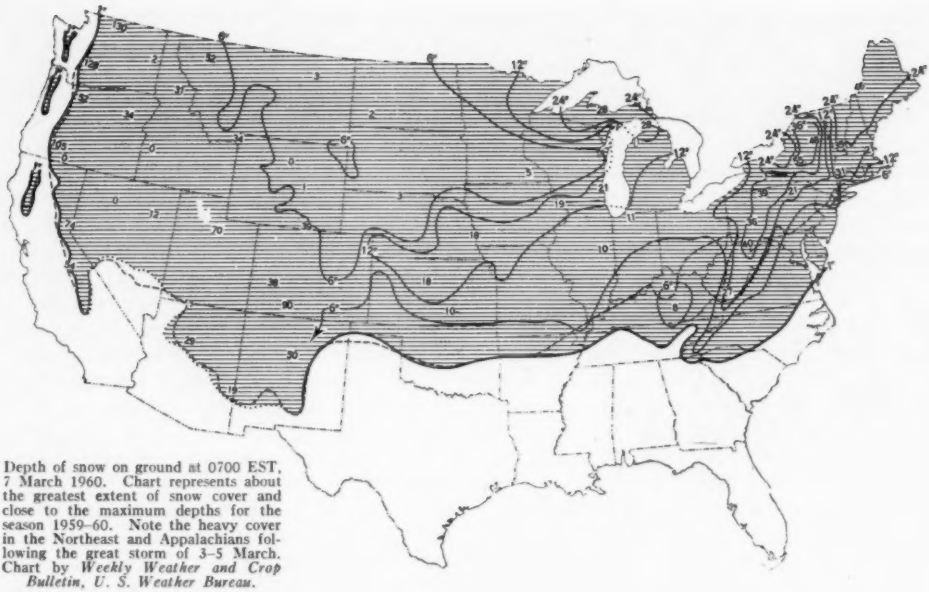
NEW YORK STATE

Heavy snowsqualls occurred along the lee shore of Lake Erie and Lake Ontario on 18–19 November with some spots reporting 18″. On the 28–29th a winter storm spread snow and ice across the northern part of the state with many minor mishaps occurring. The first week of December brought another snow situation that was particularly severe in the southwestern counties inland from Lake Erie where 18″ and 40–50 mph winds piled up huge drifts.

A small low center moving across Pennsylvania on the 21–22 December caused a very heavy fall in the extreme southeast where the northern suburbs of New York City had up to 15″ to provide a white Christmas. Amounts were light to moderate over the remainder of the state. For a 72-hour period on the 27–29th an extensive southwestern storm caused severe icing and heavy snow in the north. The Rochester area suffered its most severe glaze storm as ice of 1-inch thickness formed on exposed objects, cutting off electricity from more than 30,000 homes and putting 4,500 phones out of service in that city alone. Across northern New York heavy snows of close to 12″ fell.

In January a series of severe winter storms swept the state. On the 4–6th strong-to-gale force winds battered the western part with 22″ new snow piling up at Turin, a famous ski spot. Again on the 8–9th gales and snowsqualls struck with sufficient force to blow a Greyhound bus from the road and to drift snow in 10-foot heaps in Oneida and Lewis counties. On the 12–13th moderate to heavy snow, sleet, and freezing rain combined to give upstate areas the worst storm of the season so far, and these conditions were repeated soon after on the 15–16th. From the 16th to 18th snowsqualls in Cattaraugus County dropped 39″ of new snow. In a final January storm 10″ more covered east-central counties. The greatest January total came at Boonville with 69.5″ and also the great depth on the ground—44″.

February repeated the snowy pattern of January. The Thruway area in central New York had a particularly tough time. On the 6–7th up to 9″ impeded traffic. On the 14–15th near-blizzard conditions developed in central and western sections. Snow depths ranged up to 24″ with widespread industrial disruptions resulting. Again on the 18–19th severe winter conditions with destructive winds and another 24″ of new snow buried the region with drifts of 15 to 20 feet across highways. In a one-mile section of the Thruway, 300 cars, 90 tractor-trailers, and six buses were immobilized. At the month's end another near-blizzard occurred with a 72 mph



Depth of snow on ground at 0700 EST, 7 March 1960. Chart represents about the greatest extent of snow cover and close to the maximum depths for the season 1959–60. Note the heavy cover in the Northeast and Appalachians following the great storm of 3–5 March. Chart by *Weekly Weather and Crop Bulletin, U. S. Weather Bureau.*

wind compounding the huge drifts in the western section. The greatest monthly snowfall totaled an even 100″ at Little Valley just inland from Lake Erie, and the greatest depth on the ground again at Boonville with 60″ on the 27th. In contrast to these rigorous conditions upstate, New York City enjoyed a mild month with only 1.6″ to contend with.

March came in a very cold month, setting near-records for persistence of cold in all parts. Some places had not had so cold a March atmosphere since 1872! In Rochester's long record it was the third coldest March, and the seventh coldest at New York City. The major storm of the month came on the 3rd and continued until the 5th. From a trace of snow in the extreme northwest, depths increased to a foot in the Albany area and to a maximum southward of 44″ at Tannersville (1950′) in the Catskills. On Long Island the storm proved unusually severe as 24″ of snow completely paralyzed industrial activity. Tannersville carried off the record for the greatest March snow in the state with 58″ and a maximum accumulation of 72″ at the conclusion of the early March storm on the 6th.

CENTRAL APPALACHIANS

The first significant snow of the season moved over southwestern Virginia on 6–7 December when 6″ fell. Another light fall came on the 19th but melted quickly.

A very heavy storm for the region spread over all Tennessee except the southeastern corner on 5–6 January. Falls exceeded 5″ at practically all locations with amounts ranging up to 15.9″ at Waynesboro. Over much of the state it was the heaviest snowfall in eight years. In Virginia the top amount was 8″ and in North Carolina 12″.

Another major snow spread over Tennessee, North Carolina, and Virginia on the 13–14th. Amounts over the Cumberland Plateau reached 10″ with some exceptional amounts in eastern Tennessee: 19″ Monterey, 18.8″ Knoxville, and 17.1″ Monteagle. In Virginia the new cover reached 16″. North Carolina had snow, sleet, and freezing rain, all of which struck a devastating blow at locations unaccustomed to these varieties of nature.

A second storm moved over Tennessee on the 17th with another 5″ general but with higher amounts over the Cumberland Plateau: 15″ at Oneida. The total February fall at

Allardt of 27.9″ has been exceeded in only one previous month—January 1905 with 36″.

March, proving the coldest in Weather Bureau records for the central Appalachians, also produced some notable snow amounts as a series of Gulf of Mexico depressions moved northeastward. On 2–3 March a sheath of ice spread over higher elevations in the southern and central mountains as far south as Alabama, forcing many persons to evacuate their homes due to loss of power and heat. In North Carolina and Virginia very heavy snows fell in this storm; 20″ were common in western Virginia and 12″ in North Carolina. Another storm followed on the 9–10th when Asheville had 11″, Hickory 9″, and Winston-Salem 10.9″.

Immediately thereafter, another storm swept up from the Gulf of Mexico on the 11–12th. Snowfall again was heavy in the central mountains where accumulations reached 36″ over a wide area in the tri-state region, and in higher elevations of West Virginia ran as high as 50″. Along the Carolina coast, too, snow fell in unprecedented amounts for March—Cape Hatteras had 9″ which equaled the total of all March snows ever measured there during this century.

A final March storm on the 16th, though not as severe as the preceding ones, continued the snow accumulations at record depths. Virginia falls ranged from 2″ in the Piedmont to 14″ in the Shenandoah Valley. Some state total March figures were: Tennessee, Mountain City (2437′) 39″; North Carolina, Boone (3360′) 56.5″; West Virginia, Kumbrabow State Forest (3210′) 100.4″; Virginia, Independence (2600′) 47.5″.

THE GULF STATES SNOWSTORM

A snow commenced in the Texas Big Bend area on 12 February with amounts generally ranging from 3″ to 7″ in a broad band from the Rio Grande River to northeast Texas where some locations had as much as 12″. City points such as Houston measured 4.4″, and unofficial reports from the Beaumont-Orange area spoke of 8″ to 10″.

In southwestern Louisiana all snowfall records at Lake Charles tumbled with the 5.0″ which fell there. In a strip from southwestern to northeastern Louisiana falls ranged from 10″ to 12″. At Avoyelles the 9″ was the greatest amount in a single storm since records commenced in 1891. New Orleans was well south of the heavy belt receiving only 0.6″. Top amount for the state was measured at Colfax with 13″.

The storm also reached over into northern Mississippi where Aberdeen in the east-central region had 14″ and State College witnessed an accumulation of 11″ on the 14th. Farther east in Alabama the storm reached major proportions in the north—Moulton measured 16″ and a sizable belt had 10″ or more. The storm was quite similar to one occurring on the same dates in 1958.

MIDWEST SNOW BELT

A heavy snow belt persisted from Kansas and Nebraska northeastward to southern Wisconsin and southern Michigan early in 1960 as lows from the southern Plains moved northeastward across the middle Mississippi Valley. On the 1st and 2nd of January a snowstorm dropped 12″ in most of Nebraska and adjoining states. The main storms, however, came in a series on the 11–12th, 14–15th, and 16–17th. A total of 26.5″ fell at West Point, Nebraska, in January, and David City measured 20″ on the ground on the 20th.

The greatest storm of the winter reached blizzard proportions on 9–10 February. It was judged the worst February storm in many years in southeastern Iowa communities. Winds hit 55 mph to whip snow into deep drifts; with traffic completely paralyzed, some communities were snowbound for 3 to 4 days. At Albia and Indianola, in Iowa, 16″ of new snow fell in the blizzard. At the end of the month snow had exceeded all February records for the past 70 years at several southeastern Iowa localities. On the other hand, some northwestern Iowa places had the least February snowfall in many years.

The blizzard of 9–10 February reached over into Illinois where Freeport and Rockford, both sizable industrial cities, were isolated for 24 hours by the drifting snow. Kansas, too, shared the excessive snowfalls of the month. Sharon Springs received 34″ and some stations reported more than 25″ on the ground as the month closed.

The severe winter spell that set in on 20 February continued until the final week of March. In Kansas three storms in the first

half of the initial spring month increased the cover to record proportions at many north-central and northeastern stations with 25″ to 30″ on the ground. Snowfall throughout Kansas was generally the greatest for March since 1930. Several stations reported continuous snow cover for 68 consecutive days ending on 21 March. It was the same story in Iowa: Burlington's 16″ and Council Bluff's 25″ were the deepest cover ever reported at these stations. At Dubuque the total of 68.8″ during the winter was the snowiest season in the 98 years of record there.

Across the Mississippi in Illinois the southern portions of the state received more snowfall than the northern part. Medora, near St. Louis, had 27.8″ total March fall to lead the state. After two good falls on 21 and 25 February, three storms on 2–3, 9, and 16 March piled up the largest accumulations in 50 years. The deepest cover in southern Illinois amounted to 22″.

In Nebraska, after the final big storm of 15–16 March, many locations had their deepest-ever snow cover: North Omaha Airport 33″ and Clay Center 35″.

SOUTHEASTERN WISCONSIN

The southeastern corner of Wisconsin bordering on Lake Michigan had a big snow season in 1959–60. Substantial amounts fell in each month from November to March to give almost continuous ground cover after late December. The first big storm of the season hit the state on 22–23 December when 5″ to 20″ fell, the smallest amounts being in the northwest and the largest in the southeast close to the storm track. They were the heaviest December falls in 20 years in the southeast: Milwaukee 12.4″ and Madison 9.3″.

January totals at Milwaukee ranged well above normal with 19.4″ measured, but the major storm of the winter did not come until 9–10 February when one of the worst storms in recent years raged at blizzard proportions over the southeast. The storm dropped an additional 17.8″ at Milwaukee to raise the depth there to 20″ and this was sustained for the rest of the month. Milwaukee had an impressive February total of 34″, to be followed by a 14.3″ fall in March, again well above the normal figure.

The season's total at Milwaukee of 93.3″ was more than twice the normal of 46″ and represented the snowiest winter of the present century, though surpassed by the 110″ in 1885–86. Racine, just south of Milwaukee and also exposed to northeasterly lake gales, had 86.1″; and Kenosha, near the Illinois border, had 69.5″. Lake locations to the north, however, reported only slightly above normal totals: Sheboygan 55.6″ and Port Washington 60.5″. Inland at Madison the winter brought 49.2″, well above the average of 35.8″.

NEW MEXICO

On 14–16 December a heavy snowstorm blanketed the central portions of New Mexico with a layer of snow ranging in depth from 6″ to about 30″. In many respects it was very similar to the December 1958 storm in the same area. Snow and rain began on the 14th, becoming heavy snow on the 15th, and continuing intermittently into the 16th. In the Rio Grande Valley from Sandoval County southward to Sierra County snowfall ranged from 10″ to 14″. In the central highlands depths generally varied from 10″ to 30″, while over the central portions of the eastern plains, 6″ to 18″ were reported.

At Albuquerque a fall of 9.9″ was the second heaviest 24-hour snowfall of record for the station, being exceeded only by the 24-hour snow on 28–29 December 1958 when 12″ were measured. The 14.7″ total for Albuquerque in December 1959 exceeded any previous monthly fall.

HELENA, MONTANA

The season of 1959–60 in western Montana provided an outstanding example of very heavy early and late snows. This is a normal pattern in that region where winter is often arid and frigid. The biggest snow of the winter came on 10–11 November 1959 and proved to be the most intense fall ever measured at Helena, the state capital, since the commencement of records in 1880. A total of 21.5″ came in 24 hours for the greatest such fall ever recorded in any month. The month also was the snowiest November in the 80-year record with a total of 32.9″.

Monthly totals for the next four winter months were remarkably even—4.5″, 4.9″, 3.7″, and 4.5″—and were below the normals

for those months. But late April once again brought an out-of-season deep fall from the 22nd to the 24th. Helena had 19.4″ in this storm, and some higher elevations reported up to 30″. Secondary roads were blocked for 2 to 3 days by the spring snows.

PACIFIC COAST

The mountain areas of the Pacific Coast had a disappointing snow season in 1959–60. Only in the northwest did snows approach the normals. In most of California and adjoining portions of Nevada the prospective water supply reached critical levels. With the failure of any substantial spring rains to materialize, the interior basin areas experienced prolonged drought throughout the summer.

January was the only month in the southern mountains which produced sizable snow falls. The Snow Laboratory in the central Sierras near Truckee measured 115.9″ in January, to compose about one-third of the season's total of 325″, well below the normal. The eyes of the nation and the world were then on Squaw Valley, close to the California-Nevada border at 6226′, where the Winter Olympics were staged in February. Though a lack of snow in December raised some alarm, a bounteous January deposited 94″ to insure a superabundance of white covering for the contests. Farther north near Oregon the Mt. Shasta Ski Bowl at an elevation of 7841′ had totals of 150″, 134″, and 131″ in January, February, and March, to provide good sport and good water reserves for that part of northern California.

In Oregon at the usually snowiest location, Crater Lake (6475′), only March contributed over 100″ toward the seasonal total of 470.2″, a figure equal to only about one-half the depths there in some recent record years. At Government Camp, March also was the biggest producer contributing 83″ toward the season's total of 310″ at that 3900′ elevation.

The Cascades of Washington had a close to normal snow season with March also being the best producer there. The main storm of the winter came on 8–10 March when the following falls were recorded: Rainier Paradise Station (5550′) 33″, Snoqualmie Pass (3020′) 49″, and Stevens Pass (4085′) 34″. A total of 144″ fell at Snoqualmie Pass during March to raise the season's total to 470″ at that important highway location.

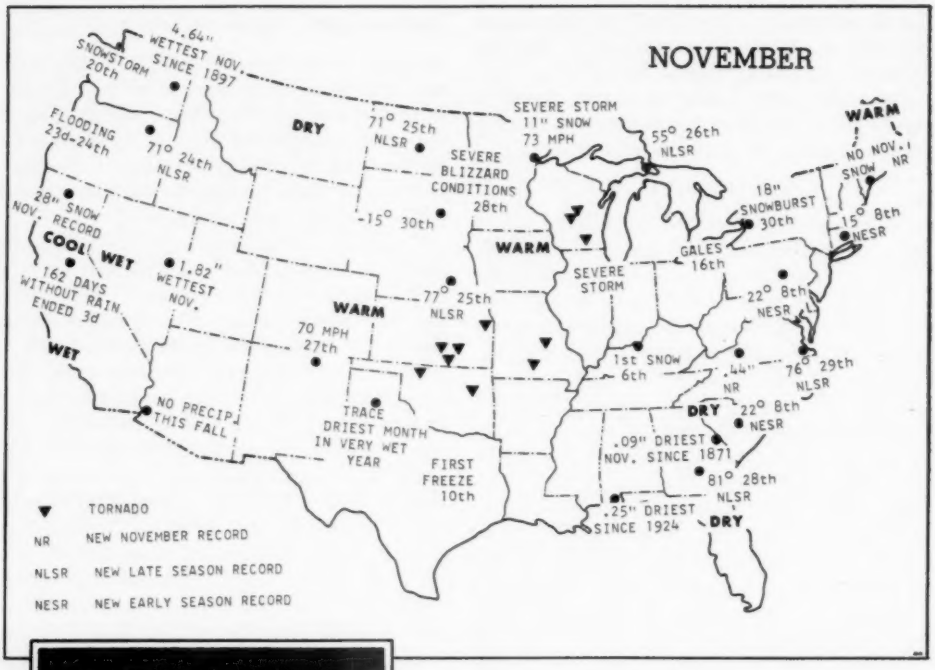
Tornadoes (*Continued from page 17*)

rather than the typical funnel. As has been reported before, there were a number of very small tornadoes or secondary funnels around the main tornado and most of these were to the south of the principal vortex. As is characteristic of these secondary tornadoes, damage was spotty, but extensive.

Probably the most important scientific data compiled in connection with this series of tornadoes were the radar photos. These show that the initial thunderstorm development to the west of Topeka was unusually rapid. During the first hour, the thunderstorm cell developed to 45,000 feet as measured by radar. Marble-sized hail fell within about 30 minutes from the time the echo first appeared on the scope and the first funnel was observed in less than an hour. The hook-shaped echo was observed on the WSR-3 radar at Topeka only on the shorter range but was followed for about an hour. The careful damage survey shows the tornadoes to coincide, in so far as measurements permit, with that part of the hook echo which might be described as a "nob." This knob, or end of the hook, was unusually bright, but it is not known now whether the unusual brightness is associated with precipitation or debris.

Of particular interest is the coincidence of the circular knob with the damage path, suggesting that the radar was actually "seeing" the tornado circulation in this case. Also, it may be noted from the photo that the knob is some four miles from the nearest edge of the parent cloud. In viewing the series of radar photos in time-lapse, a cyclonic, spiral rotation around and into the circular knob is clearly shown. This same hook-shaped echo was also clearly evident from the more powerful WSR-57 radar in Kansas City which followed the hook during the same period, even though the initial range was nearly 100 miles. Finally, it should be pointed out that as each of these tornadoes dissipated, the knob became temporarily diffuse until the next tornado developed, usually a couple of miles to the north of the dissipated one.

The last family-type tornado outbreak of the year developed during the evening of 27 November over Kansas with seven unofficial tornado reports and one of these was in suburban Kansas City.



Weatherwatch

Data by Office of Climatology, USWB.

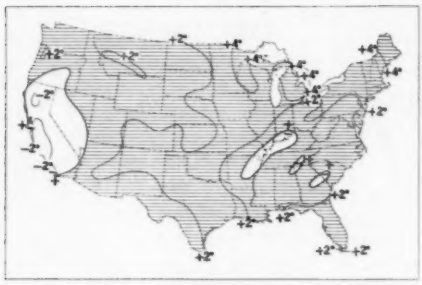
A Cold December Follows A Mild November

DAVID M. LUDLUM

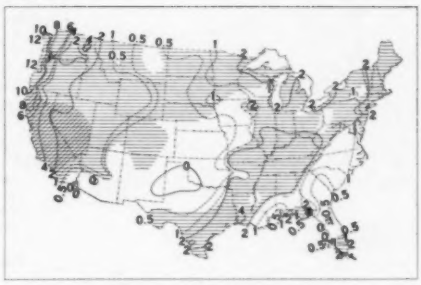
The outstanding feature of November's weather scene across the nation was the unbroken two weeks of mild Indian Summer prevailing from mid-month almost to the close. Seldom has such a large portion of the United States and southern Canada enjoyed such a long-continued and pleasant spell so late in the fall. Early November brought a varied fare, temperature-wise, with one extensive outbreak of arctic air on the 7th and 8th which drove the freezing line to the South Atlantic coast and provided a chilly week generally east of the Rocky Mountains. Despite this cold intrusion, the excess warmth in the next two weeks overcame the earlier temperature deficits to permit the month to average out as much as four degrees above normal in the Great Lakes region, the Northeast, and adjacent southeastern Canada. Only in contiguous parts of California, Nevada, and Oregon did cloudy skies and cool maritime air masses keep the mercury consistently under the November expectancies.

CIRCULATION—The pressure distribution pattern for the month as a whole was typical of a strong westerly flow type. The chief pressure feature for North America lay in a wide low pressure area south of Alaska with a trough extending along 170°W meridian into the central Pacific. An active cyclogenetic region centered off the coast of British Columbia, from whence a fast westerly jet swept through a weak ridge over the Pacific Coast States and British Columbia to a minor trough south of Hudson Bay and then directly eastward into the broad Atlantic. It was a long wave pattern with flat pressure contours and little north-south exchange of air masses except on two occasions which will be considered here.

The flow pattern across the continent during the first ten days of the month differed considerably from what would prevail later. Only once during November did the westerly index drop below the normal—during the 3rd to 7th a rather impressive ridge built up over northwestern Canada and the Rocky Mountain region of the United States. This brief period of anticyclonic blocking permitted a central Pacific low pressure system to move inland over central California and then into the southern Plateau where



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

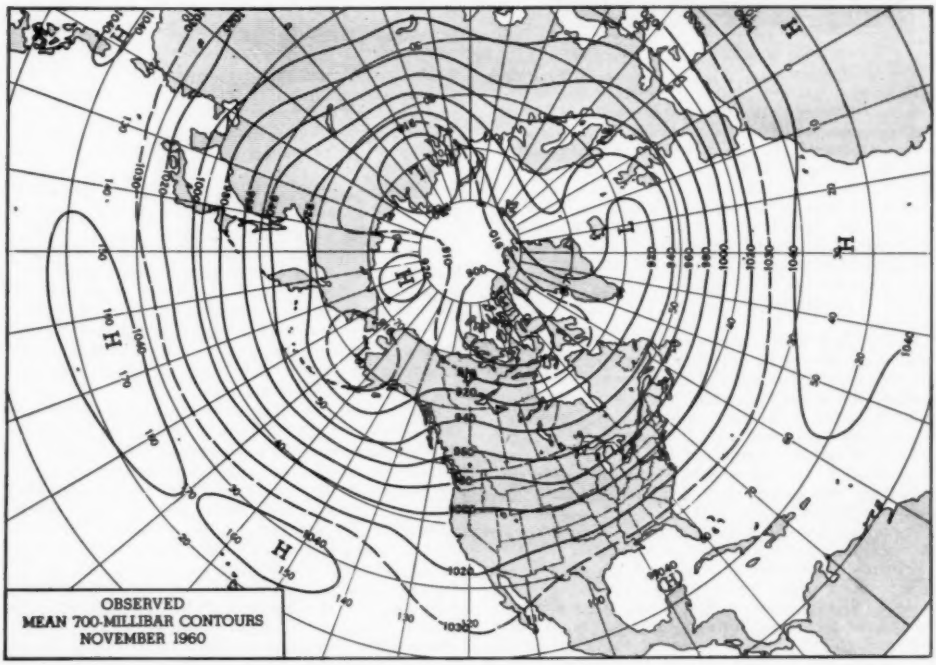
desperately-needed precipitation fell from the 3rd through the 7th. The blocking ridge also set the stage for the contemporary outbreak of cold air to the east of the Rockies.

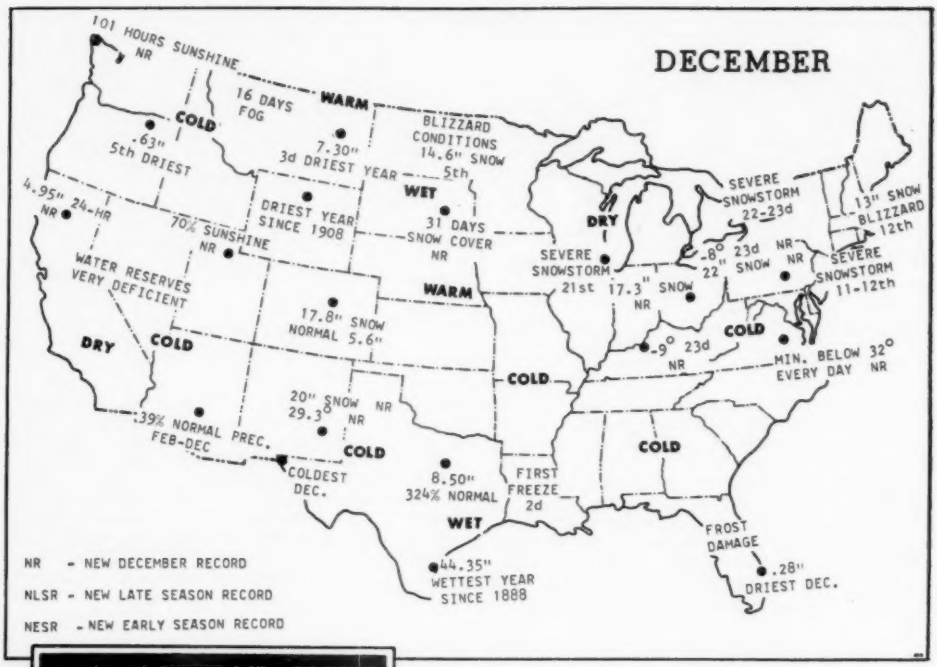
After this short period of meridional air flow, the streamlines flattened out as ridges disappeared and trough filled so that westerlies could rush Pacific air masses directly across the breadth of the continent without hindrance. Temperature fluctuations at Chicago reflect the persistence of the westerly streams and their mild character. The mercury went above normal at the Windy City on the 11th to institute a 17-day stretch of above normal readings. Thermometers soared to 70° on the 14th as the wind direction shifted more southerly at the approach of the first of two important Colorado lows which were to provide storm fans with their only excitement this month. On the 15th, as the low center was advancing northeastward over the Plains, the mercury at Chicago averaged 23 degrees above the date normal.

Air currents following the passage of the active

(*Continued on page 36*)

The upper-air map below shows the pattern of air flow for November at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.





Weatherwatch

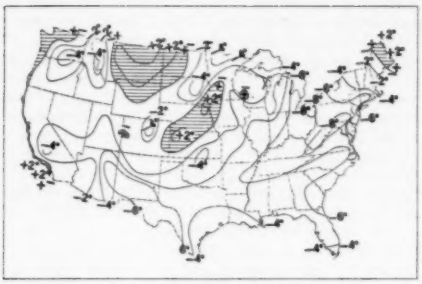
Data by Office of Climatology, USWB.

The winter season of 1960–61 on the Great Plains arrived with icy impact during the final days of November when an arctic air mass swept out of Canada and dropped temperatures to low figures that were comparable with the record lows established in that area in November 1896, the standout early winter month of all-time. The cold front ended a period of Indian Summer, extraordinary both for its degree of warmth and persistence. It served as a preview of what was to follow in the wintry month of December when temperatures in much of the East would average *much below* in contrast to the *much above* figures of November.

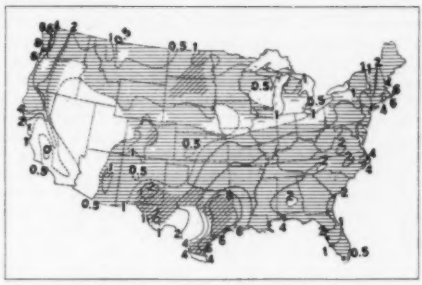
CIRCULATION—The air flow pattern as exhibited by the mean upper-air charts depicting the pressure distribution for the entire month closely resembled the classic type that produces an extremely cold December in the Eastern States. Oddly enough, it was only two years ago, in December 1958, that an almost similar example of the cold-type December prevailed. In the present December under consideration the charts showed a very strong ridge over the Plateau region of the United States and the western provinces of Canada with a strong arm jutting directly northward into the Arctic Sea to 80°N. The marked northward extension of the ridge served to separate a broad center of cyclonic action in the Aleutian Islands area of the Pacific from a trough feature over eastern Canada. Except for the first few and the final days of the month, Pacific air masses were denied entrance to the continent by the ridge; arctic air was free to rush southeastward and sweep around the vortex over central and northern Quebec; and the clashing air masses in the trough along the Eastern seaboard produced several remarkable storms.

The mean sea level maps for the month showed a great preponderance of excess air mass over western Canada where barometers averaged 7 mb/.22″ above normal in British Columbia and Alberta—to the east in Hudson Bay and Quebec pressures ran 5 mb/.16″ below the normal expectancies. Thus, streamlines of air flow at the surface and aloft ran from the western ridge to the eastern trough, circling cyclonically through southern Canada and northern United States, a path which opened all of Eastern United States to the import of cold air masses.

For the first ten days of December the layout of the weather maps somewhat belied the ultimate character the month was to assume. After the passage of the first winter anticyclone eastward on 28–30 November, an energetic trough moved into the Plateau area and soon developed an independent circulation over Arizona and New Mexico. This cut-off low whirled about in a tight circle from the 5th to the 9th with winds aloft approaching 100 knots. Directly north of this feature a strong ridge quickly built up over the northern Plains and British Columbia. Pressure mounted surprisingly over Idaho and western Montana on the 6th—Missoula, Mon-



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



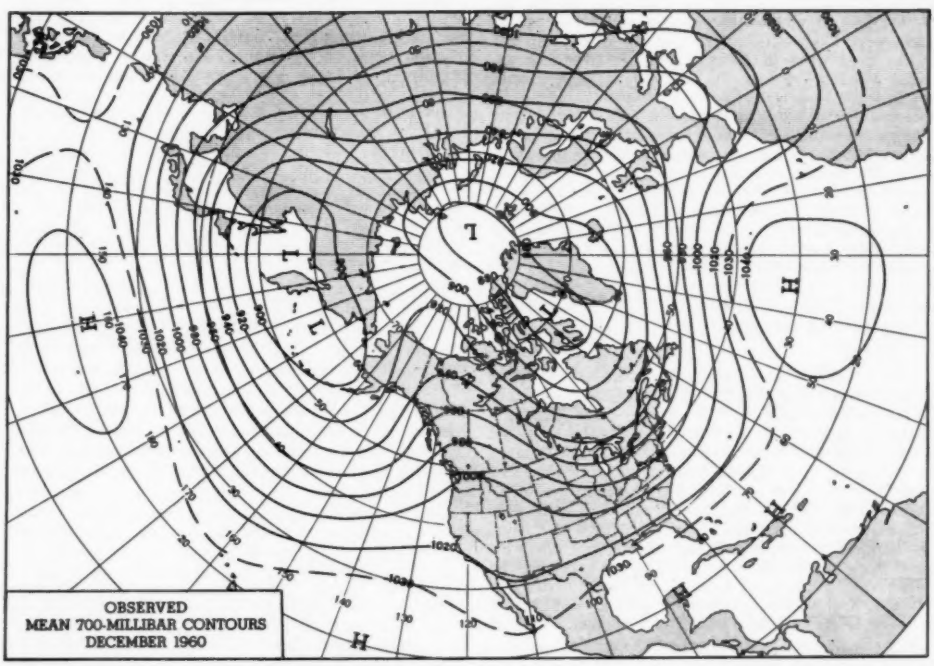
Total Precipitation in inches. USWB chart.

tana, reported a maximum reading of 1048.7 mb/30.97″.

To the south a low pressure trough persisted along the Mexican border, apparently related to the cyclonic vortex aloft over Arizona. Pressure at the surface read in the neighborhood of 1012 mb/29.89″.

Conditions remained somewhat stable until the 9th when the low vortex over the Southwest commenced to travel eastward. At the same time the upper-air ridge over the northern Plateau underwent a massive development northward to reach almost to the North Pole. The build-up of surface pressure over the Northwest Territories pushed arctic air down the eastern flank of the ridge straight from the polar region. On the 10th a new anticyclonic center had taken a position over Manitoba, ready for the conflict with the developing Southwestern low that was to produce the most spectacular weather event of the month. This story will be featured separately at the end of this column.

For the ten days following the creation of the above pressure alignment, from 10 to 20 December, the weather map showed a persistent western ridge-eastern trough pattern. The westerly flow index sank to its lowest point for the month as the massive ridge over the Canadian Northwest blocked off the continent from influences emanating from the Pacific Ocean. Cyclonic activity controlled the scene in the Eastern States and especially along the Atlantic seaboard. Low centers moved northeastward toward New England and the Maritime Provinces, then took a northerly course toward the cyclonic rendezvous over northern Quebec. A deep polar vortex there became the dominant feature of the circulation charts.



The Quebec vortex reached its maximum development on the 18th when surface pressure at the northern tip of Quebec dropped to 962 mb/28.40″. To the west in the Mackenzie Basin a 1050 mb/31.00″ anticyclone made an appearance, also on the 18th. After gathering strength for two full days on the Arctic Coast, the center of the intensely cold air mass was set in motion southward, increasing in magnitude and scope along the way till a peak pressure of 1054 mb/31.13″ was reached early on the 20th. The cold air flowing out of the core of the high struck the Great Lakes region on the 20th to tumble temperatures to zero and below. Chicago registered −1° early on the 21st. Both the 21st and 22nd were bitter days in most of the Upper Mississippi Valley and all of the Midwest. Minneapolis had a maximum of only zero on the 22nd.

The morning of the 23rd rated among the coldest December mornings ever experienced from Illinois eastward through the Ohio Valley. At Chicago's Midway Airport the mercury registered −14°, a mark that has been exceeded in downtown Chicago only eight times in any month in the past 50 years. At O'Hare Airport in the northwestern section the minima that morning was −17°. Southward in the central Ohio Valley, the thermometer sank to −9° at Louisville for the lowest December reading ever observed there.

A warming trend set in quickly as the vast surface anticyclone moved southeastward across the Mississippi Valley, and the upper-air ridge flattened out sufficiently to permit the westerlies over British Columbia to bring mild Pacific air into the Great Plains to replace the arctic stream which had prevailed for ten days. Chinook conditions over the Rocky Mountain slopes brought some spectacular temperature rises on the 23rd and 24th. Pierre, South Dakota, hit 46° on the 24th, and Chicago rebounded to 41° on Christmas Day, up a full 55 degrees in 36 hours.

The final week of December presented a less extreme pattern. In general, a western ridge-central trough-eastern ridge system controlled atmospheric movement across the continent. A fast westerly flow now swept southern Canada, confining arctic air to the north while pushing small cyclonic disturbances across the breadth of the Dominion at a fast pace. Southward in the United States, a large ridge of high pressure stretched west-to-east from the Pacific to the Atlantic and served from the 27th to the 30th as a safety isle of clear, mild weather between the cyclonic activity over Canada to the north and another stormy area to the south from Texas across the Gulf of Mexico to Florida, a region where the closing days of December saw much cloudiness and precipitation.

THE PREWINTER SNOWSTORM IN THE NORTHEAST—A major storm situation began to take shape on 9 December as a surge of arctic air pressed southward toward the Great Lakes at the same time that a frontal wave, which had formed in the Gulf of Mexico and spread precipitation over the Gulf States, showed tendencies of heading northward. By noon of the 10th the arctic front had reached the Albany-Chicago-Sioux City line with an extremely cold air mass pushing behind; and the disturbance in the Gulf had become better organized, developed a closed circulation, and moved inland close to Galveston still pursuing a northerly course.

For the next 12 hours the Gulf-Texas disturbance, having joined the eastern flank of an upper-air vortex moving eastward from Arizona, continued its rather unusual track directly northward to southwestern Missouri. Here about midnight of the 10–11th the system came under the blocking influence of the northern anticyclone. A remarkable, abrupt turn of 90° to the east was forced on the advancing low center which then skirted the southern border of the cold air mass and reached the western slopes of the Appalachians in east Tennessee before noon of Sunday, the 11th, with pressure at 1004 mb/29.65″. Light to moderate snow spread from central Missouri through the Ohio Valley to the Pittsburgh area with the heaviest amounts near 5″.

On that same morning, another snow area seemed to break out in Virginia and Maryland and push rapidly eastward to the New Jersey coast by noon. This was indicative that important developments were under way in transforming a moderate mid-Mississippi Valley disturbance into a major coastal storm. With the northern anticyclone crested near Lake Superior at 1032 mb/30.48″, a long ridge arm extended eastward to the coast of New England with zero temperatures prevalent through the upper Great Lakes, St. Lawrence Valley, and northern New England. The presence of a cold-air ridge with a west-east axis is a prerequisite for a heavy snowstorm situation in the Middle Atlantic States. The ridge performs a double pincer action on the low to the south: the eastern encircling arm pushes cold air out over the waters of the Atlantic, well in advance of the developing low to the south, so that later below-freezing temperatures are maintained in the increasing northeasterly flow ashore. Otherwise, relatively warm Atlantic air will enter the circulation and soon change snow to rain.

The western pincer rushes cold air in a fast northerly stream across the Ohio Valley and down the slopes of the Appalachians where it enters the circulation of the coastal low. There it clashes with the current of tropical air moving northward along the eastern flank of the low. This conflict appears to supply the dynamic energy for the rapid deepening of the northward advancing storm center and the subsequent creation of a heavy precipitation pattern.

All of these atmospheric actions were in process early on the 11th as a secondary storm center formed just east of the mountains in the central Carolinas. As the new center moved off at a fast clip to the northeastward, the mantle of snow mentioned above spread rapidly northward, commencing at Roanoke about 0700, Washington 0900, New York 1400, and Boston 2200.

The storm track passed off the coast just southeast of Norfolk late on the 11th and by 0700/12th had progressed to a point about 250 miles directly east of Atlantic City. The light to moderate snow of the 11th became heavy snow from Maryland to Connecticut and with the intensification of the storm center the heavy fall continued for about 12 hours. On the 12th the deep snow belt extended through central New England to the southern Maine coast. Central pressure of the low at 0700/12th had dropped to 978 mb/28.86″.

During the daylight hours of the 12th the center made a significant turn to the northward and slowed its forward pace somewhat, both actions contributing to a prolongation and intensification of the precipitation process from New Jersey through New York to New England. This was especially noticeable in the New York Metropolitan area where snowfall again became heavy around the noon hours of the 12th after having slacked off a bit in mid-morning.

The belt of heavy snow with falls in excess of 10″ began on the Baltimore-Harrisburg line. It extended northeastward, but generally inland from the coast. Along the immediate shoreline in New Jersey and Connecticut falls were only moderate, in the vicinity of 7″, except in the New York Metropolitan area where the configuration of the coastline seems to favor heavy snows. Twenty miles inland, from Maryland to Connecticut, falls were double the amounts received at coastal points. Though Block Island, R. I. reported only 6.3″, Nantucket Island, 80 miles to the east and close to the storm track, had 15.7″ and gusts of wind to 70 mph.

The Prewinter Snowstorm of 1960 will long hold a unique place in the snow annals of the Northeast. In the New York Metropolitan area it deposited one of the largest amount ever received in a single snowstorm. In the downtown city records, which in combination with the Central Park figures date back to 1869, only the 20.9″ in the Blizzard of March 1888 and the Big Snow of December 1947 with 25.8″ have exceeded the 20″ figure. It was also the heaviest snow ever measured so early in the season. But this was only the start of a near-record snow season for New York as two more major storms were to strike later: 9.9″ on 19–20 January and 17.4″ on 3–4 February. The seasonal record of 63.2″ in 1947–48 was in sight.

From the meteorological point of view, the storm combined the three main elements of a severe winter storm: heavy snow, high wind force, and low temperatures. At Newark Airport, New Jersey, where the greatest fall of 20.4″ was measured, temperatures hovered around 20° during the period of heavy fall, and the wind averaged 20 mph during the day of the 12th with gusts to 30 mph. These figures approach blizzard qualifications, but do not quite make the grade, even for an Eastern blizzard.

In March 1888 the New York area had 40-mile gales and temperatures close to 10° during the height of the storm on the 12th. So the Prewinter Snowstorm of 1960 will rate as just a heavy snowstorm, in the annals of New York, but a memorable one. Closer to the center of the storm track over eastern New England, winds were higher: Boston averaged 26.6 mph with the fastest mile clocked at 40 mph, and Nantucket averaged 35.8 mph with the fastest mile at 51 mph. With these figures in mind, the Boston weatherman concluded: "the storm was a true 'severe blizzard,' a unique December phenomena in this area."

Have early December storms in the pre-Weather Bureau period ever exceeded the 1960 totals for early December? One has to hark back to 1786 when two major snowstorms struck within a week of each other in early December to pile up record prewinter totals. On 4–5 December 1786 an intense coastal storm dropped 18″ at Morristown, New Jersey, and 20″ at Hamden near New Haven in Connecticut. A second and even more intense northeaster brought another 21″ to Morristown and 17″ to Hamden on the 8–9th. At Salem, Massachusetts, 12″ were measured on the 5th and another 10″ on the 9th. The Boston press at the end of the week reported the snow cover at "nearly four feet." Ezra Stiles, the weather-watching president of Yale College, thought the snow depth on 10 December as the greatest New England had seen since the much-revered Big Snow of February 1717.

CANADIAN HIGHLIGHTS

British Columbia. The atmospheric pressure averaged more than 6 mb above normal over British Columbia in December 1960 as there was less than normal storm activity along the Pacific coast. There were no invasions of cold air from the north, and as a result the month was mild with fairly light precipitation and above normal sunshine totals along the coast, although there was persistent cloud in the interior valleys. It was the sunniest December at Vancouver in 15 years and the least windy at Victoria over the past 17 years. Maximum temperatures in excess of 60° were reported from several stations in the lower Fraser valley, while precipitation in excess of 15″ was reported in the Prince Rupert region. Barometric pressure at Vancouver averaged higher than any December since observations began at the airport 23 years ago.

The Prairies. As the predominant storm track was southeastward across the Canadian Prairies, mild conditions prevailed during the month with only southern Manitoba reporting below normal temperatures. Snowfall was near normal, but frequent thaws left the western prairies with a very light snow cover at the end of the month. A severe storm moved from the Dakota's into southern Manitoba and northwestern Ontario on December 5th giving near blizzard conditions in Manitoba and freezing rain in Ontario. Highways became impassable and several power lines became unserviceable.

Ontario & Quebec. Downstream from the western upper-level ridge a major trough formed across the Great Lakes region. This strong northwesterly flow aloft produced sub-normal temperatures over most of Ontario and Quebec and above normal snowfall in the lee of the Great Lakes where Muskoka and Wiarton reported more than 45″. Along Lake Erie snowfall was light and precipitation amounted to less than 50% of normal.

Atlantic Provinces. With increased cyclonic activity this month in the Atlantic Provinces, and with the general circulation more in a southwesterly than the normal westerly direction, both temperatures and snowfall were above normal for the month. The passage of deep depressions through the area brought wide swings in temperature and the increase in precipitation totals enabled some sections to show partial recovery from the drought that had gripped them for several months. At Halifax, where meteorological observations were begun in 1874, the calendar year of 1960 will go down in the records as being the sunniest, snowiest, and least rainy year of all-time.

The North. With the circulation of Pacific air over Yukon Territory during much of most of the month, temperatures in that region averaged 15 degrees above normal, exhibiting the greatest temperature anomaly on the continent during the month. Dawson had a maximum temperature as high as 46° while the average monthly temperature of 17° at Whitehorse was comparable to that at Edmonton and Ottawa. In the eastern Arctic, pressures averaged 4 mb less than normal as the Icelandic low extended farther westward than normal. In contrast to the western Arctic, Baffin Island had temperatures below normal and Eureka with a mean temperature for the month of −30° was the coldest location in the nation.

(Courtesy of Meteorological Branch, Air Services, Department of Transport, Canada)

November (*Continued from page 31*)

Plains disturbance northeastward to Hudson Bay (where pressure dropped to 968mb/28.50″) again came from the Pacific Ocean, while a frontal barrier along 60°N across central Canada contained arctic air in the polar regions. The favored storm track shifted far to the north; the area of cyclogenesis just west of British Columbia produced several fast-moving lows which crossed the northern parts of the Prairie Provinces and Hudson Bay in their eastward rush. This northerly path left all southern Canada and the United States to enjoy the mildness of Pacific air masses from the 17th through the 24th.

The major storm situation of the month began to develop on the 23rd as a North Pacific low, deviating from the previous pattern, approached the Oregon coast. Its passage inland on the 24–25th caused torrential rains to flood coastal areas of Oregon and northern California and heavy snows to pile up in the mountains. The storm track carried the center into Nevada where once again copious precipitation cheered the inhabitants.

In the wake of this disturbance, cold air pressing southward out of Canada invaded the northwestern corner of the United States, but was halted momentarily by a long front extending northeastward from the low center in Nevada to the Great Lakes. South of this front the mercury in the Midwest and East zoomed to record proportions. Bismarck, usually in the lap of a North Dakota winter at this time, hit 71° on the 25th for the highest ever registered so late in the season at that northern location. Chicago duplicated the mid-month thermal aberrations by reaching 63°, 61°, and 63° on the 26th, 27th, and 28th: for these days the average ran 17 degrees above normal. Like figures smashing so late in the season marks were registered generally throughout the Midwest, Upper South, and East.

The sharp contrast of air masses across the long front developed a vigorous storm center as the western pressure impulse moved across the Rocky Mountains on the 27th. Blocked by a large shield of arctic air overlying the Prairie Provinces, the storm center deepened rapidly over the Plains into a severe disturbance with gales and thunderstorms to the east and blizzard conditions on the western and northern flanks. Around the southern side of the deepening low, the cold front swept rapidly eastward carrying the frigid air to all sections of the country. At Chicago, our check-point for the month, the mercury plummeted on the 28th from 63° to 30° as the front swept by in the afternoon. In another 24 hours the front had cleared the Atlantic Coast to end the abnormal warm spell along the eastern seaboard. Raleigh, North Carolina, had a maximum of 73° on the 29th and a minimum of 32° on the 30th.

To return to the Pacific Coast, it should be pointed out that the prevailing westerly flow of November caused excessive rainfall there as successive frontal systems moved inland. Sacramento, California, where there had been 162 consecutive days without any rainfall had 14 rainy days in November, a mark which tied the existing record. At Portland, Oregon, it was the wettest November since 1942. The 11.33 inches which fell at Olympia, Washington, was just short of the November record. And at Mount Shasta, in northern California, more snow fell this November (28.1″) than in any 11th month since records commenced in 1888. For all the Far West the November downpours were most welcome after many months of disappointing rainfall.

CANADIAN HIGHLIGHTS

British Columbia. Temperatures were remarkably normal in British Columbia with the mean temperatures at most stations falling within one degree of normal values. Precipitation was fairly evenly distributed throughout most of the month in most areas and amounts were not excessive, although Herbert Inlet on the Pacific Coast reported 25″. This new station is gaining the reputation of being the rainiest weather reporting station in Canada.

Prairie Provinces. Temperatures were abnormally high during the first week as Pacific air flowed eastward across the Prairies. Several stations reported maxima in excess of 70°, and Gleichen, Alberta, had 72°, the highest temperature during the month throughout the nation. By the end of the month, however, minimum temperatures of below zero had been reported throughout all the Prairies as the result of outbreaks of cold air from the Arctic. Snowfall averaged 6″ across the southern Prairies, but precipitation generally was again below normal. At the end of the month there was light snow cover over much of the southern Prairies, but all the northern areas were under a blanket of 6″ or more.

Ontario and Quebec. November was exceptionally warm in Ontario and Quebec, some stations reporting temperature anomalies of 8 degrees. Northern Ontario and Quebec were dull and cloudy with precipitation above normal, while in the south the month's weather may be described as bright, warm, and dry. In Quebec, heavy fog was experienced along the St. Lawrence Valley on 14–15 November, hampering all types of traffic.

Atlantic Provinces. Generally fine weather prevailed in November with about normal temperatures and light precipitation. Rural areas in some parts of the Maritimes were still suffering from water shortages at the end of the month; although New Brunswick was cloudier than normal, the trend of above normal sunshine in Nova Scotia continued. In fact, at Halifax, November was the eighth month with sub-normal precipitation and above normal sunshine. Sunshine totals at that city to the first of December are already greater than for any calendar year on record.

The North. While the eastern Arctic had temperatures slightly above normal, the western Arctic and continental Northwest Territories were much colder than normal. Temperatures averaged ten degrees below normal at Ennadai Lake and Fort Reliance, while the coldest temperature in the country during the month was −45° at Isachsen, N.W.T. Snowfall in southern Baffin Land was in excess of 12″, though on the far northern islands it was generally less than 1″.

(Courtesy Meteorological Branch, Air Services, Department of Transport, Canada)

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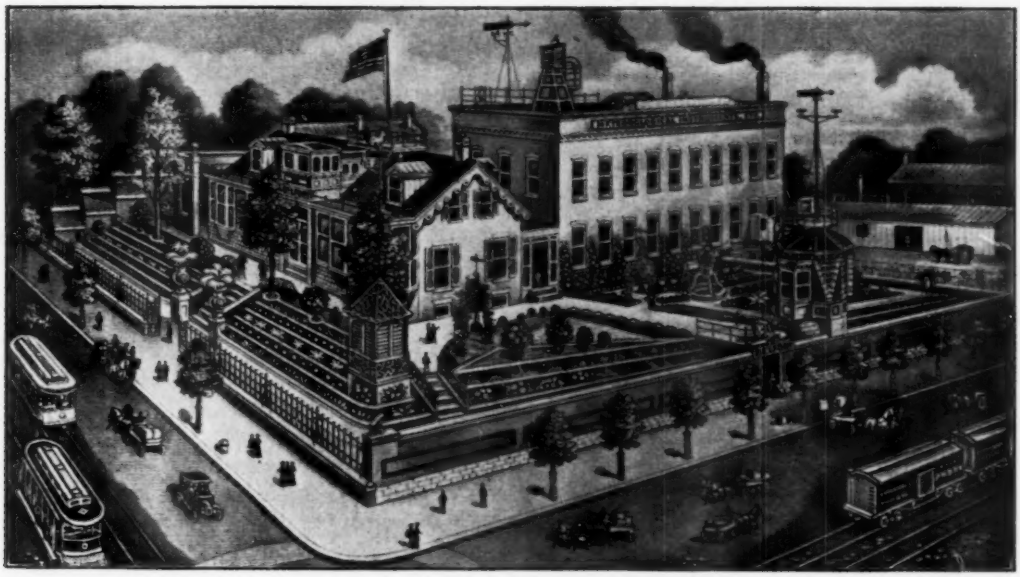

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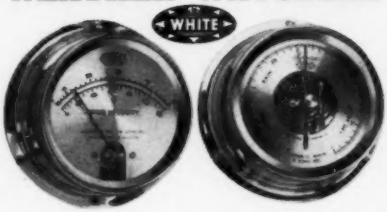

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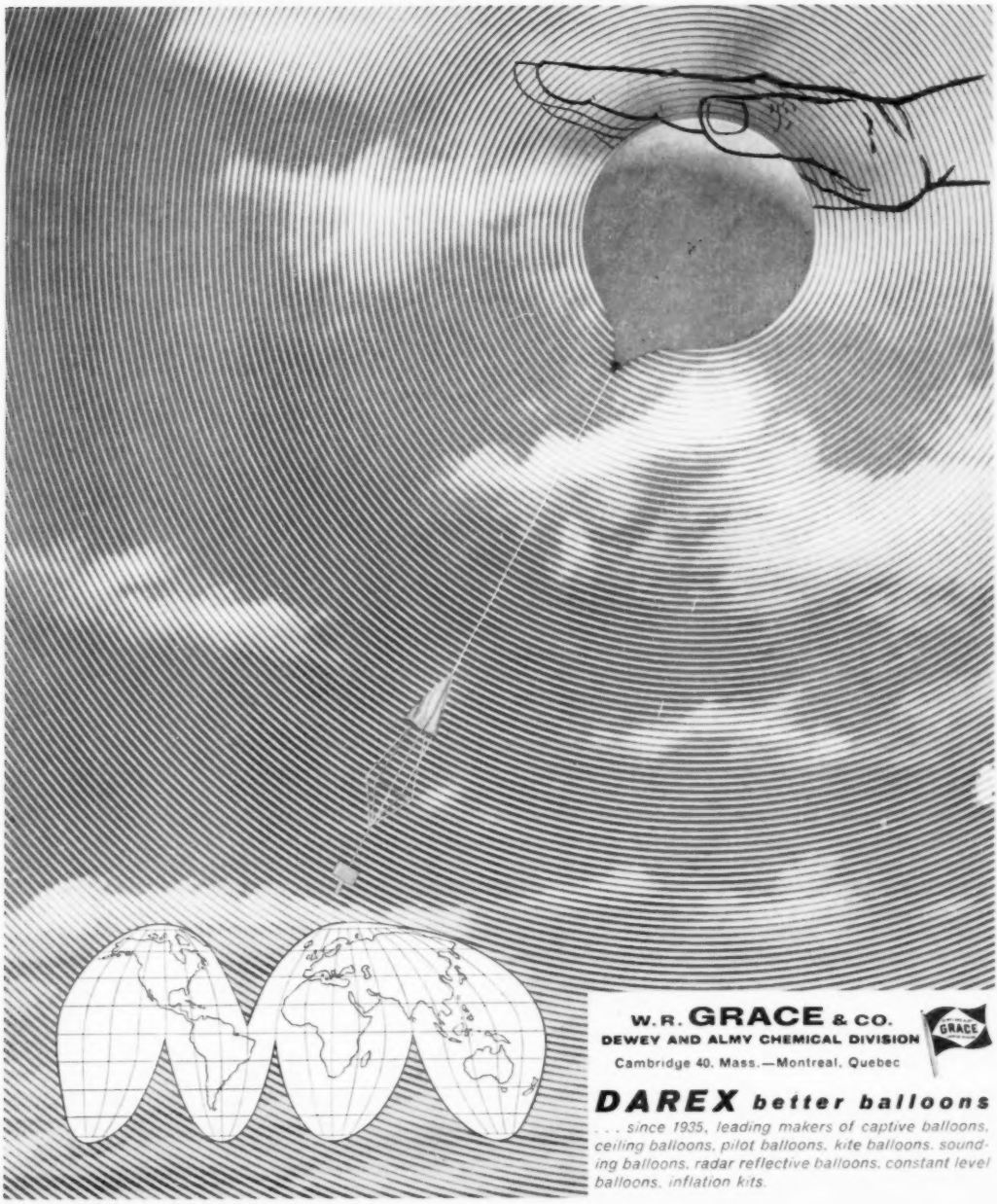

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